Assessing Recovery and Training Quality: Swimmers' Perceptions and Practices

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A thesis submitted to the Faculty of Health at the University of Technology Sydney, in fulfilment of the requirements for the degree: Doctor of Philosophy

12th June, 2020

i. CERTIFICATE OF ORIGINAL AUTHORSHIP

I, Stephanie Shell declare that this thesis, is submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the Faculty of Health, Sport and Exercise Discipline, at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise referenced or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis. This document has not been submitted for qualifications at any other academic institution.

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iii. PREFACE

This thesis for the degree of Doctor of Philosophy is in the format of Thesis by compilation and abides by the 'Procedures for Presentation and Submission of Theses for Higher Degrees – University of Technology Sydney; Policies and Directions of the University'.

Based on the research design and data collection by the candidate, four manuscripts have been submitted to peer reviewed journals for publication. These papers are initially brought together by an *Introduction*, which provides background information defines the research problem, in addition to the purpose and significance of each of the four studies. A *Literature Review* follows to provide an overview of recovery strategies and their hypothesised effect on training quality. The manuscripts are then presented in a logical sequence following the development of research ideas within this thesis. Each manuscript outlines information pertaining to the design methodology and findings of each study separately. Figures, tables and reference numbers have been retained. The *Discussion of Thesis* chapter contains information pertaining to the collective findings, practical applications and suggestions for future research based on the series of studies. This chapter additionally contains the thesis conclusion; a synopsis of the research hypothesis and conclusions from each study. American Medical Association reference style has been used throughout the document, with the reference list at the end of the thesis.

iv. PUBLICATIONS

List of Articles Submitted for Peer Review Publication

1. **Shell, S.J.**, Slattery, K., Clark, B., Broatch, J.R., Halson, S., Kellmann, M., & Coutts, A.J. (2019). Perceptions and use of recovery strategies: Do swimmers and coaches believe they are effective? *Journal of Sports Sciences, Accepted for Publication, DOI: 10.1080/02640414.2020.1770925.*
2. **Shell, S.J.**, Clark, B., Slattery, K., Broatch, J.R., Halson, S., & Coutts, A.J. (2019). Self-Report v Practice: Comparisons between swimmers' reported and observed recovery strategy use. *Journal of Science and Medicine in Sport, Under Review.*
3. **Shell, S.J.**, Slattery, K., Clark, B., Broatch, J.R., Halson, S., & Coutts, A.J. (2019).Development and Validity of the Subjective Training Quality scale. *Journal of Sports Sciences, Under Review.*
4. **Shell, S.J.**, Clark, B., Slattery, K., Broatch, J.R., Halson, S., & Coutts, A.J. (2019). Is a head-worn inertial sensor a valid tool to monitor swimming? *Prepared as a technical report for publication in the International Journal of Sport Physiology and Performance.*

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2. **Shell, S.J.**, Clark, B., Slattery, K., Miller, J., Broatch, J.R., Halson, S., Kellmann, M., & Coutts, A.J. (2018). Use of Recovery Strategies by Swimmers during Training and Competition. Queensland Academy of Sport (QAS) Applied Physiology Conference, Brisbane, Australia. 23rd November.
3. **Shell, S.J.**, Clark, B., Slattery, K., Miller, J., Broatch, J.R., Halson, S., Kellmann, M., & Coutts, A.J. (2018). Use of Recovery Strategies by Swimmers during Training and Competition. University of Technology Sydney (UTS) Faculty of Health Research Student Forum, Sydney, Australia. 29th November.

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vii. LIST OF ABBREVIATIONS

AIS	Australian Institute of Sport
BLa	Blood lactate
°C	Degrees Celsius
CFA	Confirmatory factor analysis
CK	Creatine kinase
CWI	Cold water immersion
CWT	Contrast water therapy
CV	Coefficient of variation
DOMS	Delayed onset muscle soreness
GPS	Global positioning system
H	Hours
HR	Heart rate
HWI	Hot water immersion
Hz	Hertz
ICC	Intraclass correlation coefficient
Km	Kilometres
m	Meters
m/s	Meters per second
min	Minutes
N	Sample size
PMR	Progressive muscle relaxation
RH	Relative humidity
RMSEA	Root mean square error of approximation

ROM	Range of motion
RPE	Rating of perceived exertion
SD	Standard deviation
sec	Seconds
SRMR	Standardised root mean square residual
STQ	Subjective training quality scale
UTS	University of Technology Sydney

viii. ABSTRACT

Maintaining an adequate balance between training and recovery is essential to optimise performance outcomes. Recovery is a multifaceted, time-dependent process that can promote adaptation. Numerous studies have examined the efficacy of recovery strategies, including their mechanistic and performance benefits, however, limited evidence exists examining athlete and coach recovery perceptions, and practices in the training and competitive environments. Given its importance, understanding how recovery strategies are used could improve programming and education. Training quality is important in the evaluation of training effectiveness, where increases in soreness and fatigue may lead to reduced training quality. However, training quality remains empirically undefined, with no available monitoring tools. Therefore, this thesis aimed to investigate recovery strategy perceptions and practices, describe training quality, and develop a training quality assessment tool in competitive swimmers, via implementation of a sequential explanatory, mixed methods research design.

Study One used a survey to understand swimmers' and coaches recovery strategy use, prescription, and perceived effectiveness, in training and competition. Study Two implemented a survey, and semi-structured interview for comparison between swimmers' self-reported and observed strategy use. Study Three aimed to define training quality through semi-structured interviews. Once defined, the Subjective Training Quality (STQ) scale was developed and checked for internal consistency and face validity. Finally, Study Four aimed to further validate the STQ scale in training, assessing the measurement accuracy of swimming metrics using a wearable monitoring device. However, due to the device's inaccuracy, comparisons with the STQ ratings was not possible. Therefore, future longitudinal research into the validity of the wearable device in comparison with the STQ ratings is required.

The primary outcomes of this thesis are, 1) multiple recovery strategies are used and prescribed in training and competition, with greater use in competition; 2) swimmers overestimate recovery strategy use when self-reporting, compared to observation; 3) training quality encompasses physical, technical and mental constructs; 4) initial validation suggests the STQ scale could monitor training quality; and 5) the wearable device investigated was not a valid indicator of swimming metrics. This thesis provides insight to swimmers' and coach's recovery strategy perceptions and practices, highlighting the need for tailored education and individualisation of recovery programming, to promote appropriate use. Moreover, initial findings suggest training quality and the STQ scale may provide greater insight into an athlete's training effectiveness, and enhance the coach's ability to prescribe training. Collectively, these findings provide a platform for future research into the relationship between recovery strategies, training quality and performance outcomes.

CHAPTER 1 INTRODUCTION

Repeated training sessions result in a cumulative stimulus effect to promote favourable adaptations for future performance improvements.[1] This stimuli eventually leads to improved physiological responses (e.g., mitochondrial function, fatigue resistance), and homeostatic defence.[1] The extent of these cellular and systemic responses is primarily determined by the intensity, duration and frequency of exercise.[2,3] To optimise training stimuli application, training programs will be periodised according to the desired outcomes within a week, month, or year.[4] Examples of desirable training outcomes include increasing power output, and refining technical skills.[4] To maximise the benefits of training and reduce the risk of non-functional overreaching (i.e., extreme overreaching where training and life stressors result in short-term decrements in performance capacity), the balance between load and recovery must be maintained.[5] The biological process of recovery is multifaceted and time-dependant, in which adaptive processes occur, and performance capacities are re-established or improved.[6-8]

Periods of training that are complemented with adequate recovery promote adaptation, and increase the likelihood of enhanced athletic training outcomes.[9,10] Appropriate time for recovery therefore plays an integral role in maintaining daily training capacity.[7,11-13] The importance of recovery will differ according to the training phase, number of daily training sessions, an athlete's mental and emotional state, and individual demands.[8] Regardless of these factors, time for recovery must be proactively programmed into athlete training plans to enhance recovery rate, maximise training volumes and reduce the risk of injury or illness.[6,7,11]

The appropriate periodisation of recovery has been increasingly acknowledged as an important consideration when designing athletic training plans.[10] Recovery periodisation encompasses limiting or hastening recovery according to the desired training outcomes, training phase, session type (i.e., light- versus high-intensity exercise), or in relation to environmental

conditions. Strategically removing recovery activities during the general preparation phase to maximise adaptation is one example of how recovery is modified in the daily training environment. Alternatively, during specific preparation and competition phases of training, athletes and coaches aim to hasten recovery. To accelerate the restorative process, and subsequently return physiological and psychological function to pre-exercise levels, post-exercise recovery strategies are commonly used.[11,14]

Athletes, coaches, and sport science practitioners must appropriately select and program recovery interventions according to individual and sporting demands.[7] Examples of regularly used recovery strategies include active recovery, stretching, hydrotherapy, massage and compression garments.[11] There are a myriad of purported physiological and psychological benefits of various recovery strategies. Examples include; reductions in core and muscle temperatures, oedema, delayed onset muscle soreness (DOMS), perceived fatigue, increases in metabolite removal, and upregulation of parasympathetic nervous system activity.[11,15] The degree of psychophysiological response will not only differ with the strategy used, but also in accordance with the individual's belief in the effectiveness of the recovery strategy.[16] Specifically, a positive belief is more likely to promote a beneficial recovery response, as compared to a nocebo belief effect which can result in neutral or reduced performance outcomes.[16,17] Therefore, coaches and sport science practitioners should first understand how athletes use strategies to enhance their recovery status, to enhance recovery prescription.

Pool swimming is a competitive sport requiring well-developed physical capacities and considerable technical proficiency.[18] Distances swum in competition range from 50-1,500 m in four different strokes; freestyle, backstroke, breaststroke and butterfly. Given the high training loads swimmers must complete, adequate recovery is vital to maintain training capacities and reduce the risk of non-functional overreaching.[19] However, the recovery practices of swimmers are yet to be examined, and the current objective and subjective swim monitoring tools available

typically focus on the well-being of an athlete prior to, or following a session.[20] A limitation of available monitoring tools, is they provide indication of training intensity (i.e. physical objectives) during a training session,[20] yet do not capture other constructs of performance in the training environment (i.e., mental, technical or tactical objectives). Understanding these athletic training demands could therefore be beneficial for coaches and sports scientists to enhance training prescription.

Training quality is an important consideration in the assessment of training effectiveness and outcomes, and is a recurring concept anecdotally discussed between athletes and coaches. However, training quality is yet to be empirically defined. Anecdotally, training quality is a term used to describe whether or not, the outcomes of a training session were achieved. It is possible increases in training loads subsequently leading to augmented soreness and fatigue over time, could lead to reduced training quality. If an athlete's training quality is continuously reduced, training adaptations and outcomes are also likely to decrease. Consequently, the maintenance or improvement in quality across training sessions is an important consideration for athletes and coaches. It is possible that the strategic inclusion of recovery strategies into a training program could assist in the maintenance of quality and in fact lead to improvements in training quality.

1.1 THESIS OVERVIEW

Research Problem

Previous recovery research has primarily assessed the mechanistic and performance benefits of recovery strategies, with various studies providing inconsistent findings.[21] To date, limited evidence exists elucidating athlete and coach beliefs regarding the importance of recovery strategies. Previous research examining recovery strategy perceptions and practices have used surveys or questionnaires, and primarily investigated athletes and support staff, with only one

study including coaches.[22] However, minimal research currently exists directly assessing the reasons and barriers surrounding recovery strategy use. Moreover, no studies have investigated the differences between self-reported and observed practices to understand whether athletes accurately report their recovery strategy use. While research suggests athletes and coaches are educated on the differing psychophysiological effects of recovery strategies to enhance strategy selection and implementation,[23,24] there is no research investigating the actual use, and perceived effectiveness, of recovery strategies by swimmers. Therefore, considering the importance of understanding recovery strategy practices and beliefs, further investigation is warranted.

Research Objectives

The aim of this thesis was to investigate the perceptions, practices and observed use of recovery strategies during both training and competition, and describe training quality to subsequently develop a tool to assess training quality in competitive swimmers. Prior to examining the relationship between recovery and training quality, it is important to firstly understand the current use of recovery strategies, and perception of training quality in competitive swimmers. A series of four studies were implemented to address the thesis aim through the following objectives. These objectives are further defined in Figure 1.1.

Objective One (Study One): To understand swimmers' and coaches current use, and perceptions of the effectiveness and importance of recovery strategies during training and competition.

Objective Two (Study Two): To determine the differences in self-reported and observed recovery strategy use by swimmers during training and competition.

Objective Three (Study Three): To understand and define training quality, and subsequently develop a subjective monitoring tool that could be used to assess training quality.

Objective Four (Study Four): Independently validate various swimming metrics using a wearable device.

Objective Five: Assess the longitudinal (i.e., 2 month) validity of swimming metrics using a wearable device for comparison across multiple training cycles, to enable subsequent comparison with the subjective training quality monitoring tool.

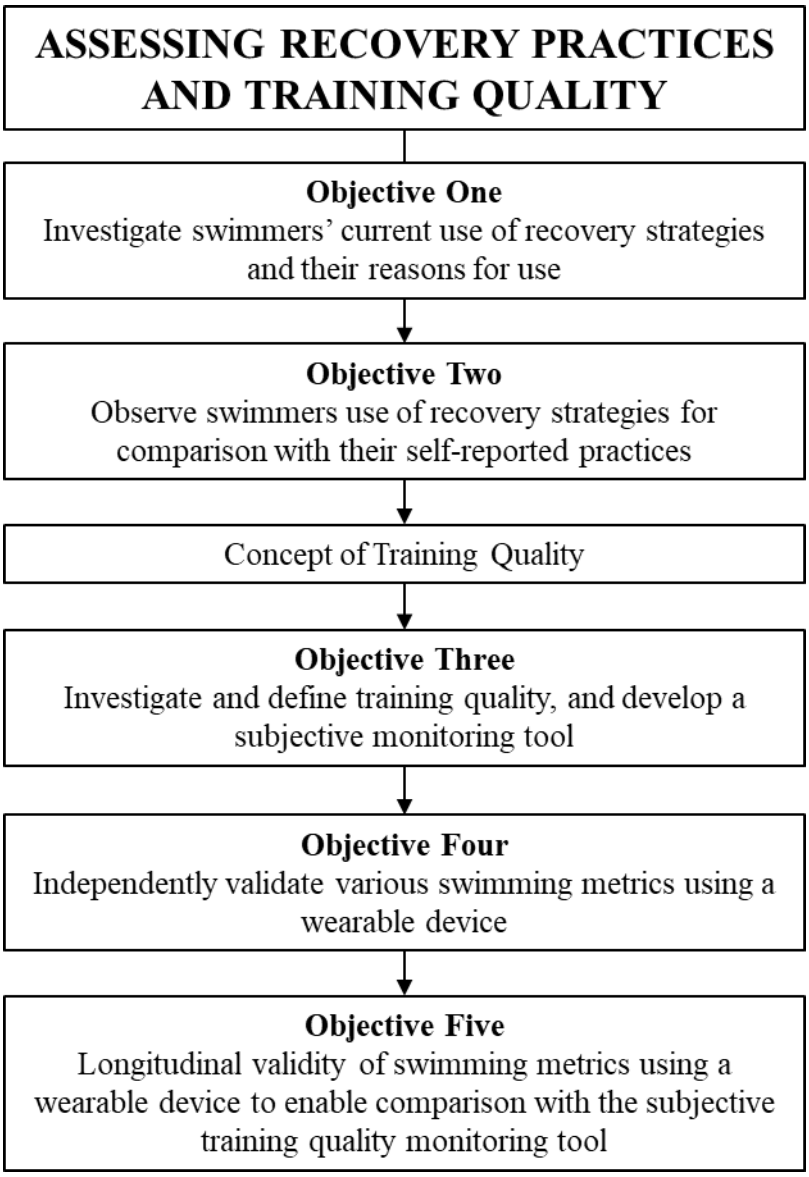

Figure 1.1 Visual flow chart representing thesis conception and research objectives.

A mixed methods approach was selected as an appropriate methodological framework to explore swimmers' use of recovery strategies, and perceptions of training quality. Mixed method research entails the process of collecting, analysing and combining quantitative and qualitative data, recognising that neither method independently provides a sufficiently robust analysis of the data.[25,26] Once collected and analysed, the quantitative and qualitative data is combined to form a comprehensive understanding of the research problem.[25] There are an array

of mixed method research designs which can be used to interrelate the data. For the purpose of this thesis, a sequential explanatory design was used. Sequential explanatory design involves the collection of quantitative data, followed by qualitative.[26] After collection and analysis of the quantitative data, the qualitative results are used to further explain and elaborate upon the findings.[26] Within the current investigation, phases one and three contained sequential application of quantitative and qualitative methodologies within each study, and phase two included qualitative extension of phase one results (Figure 1.2).

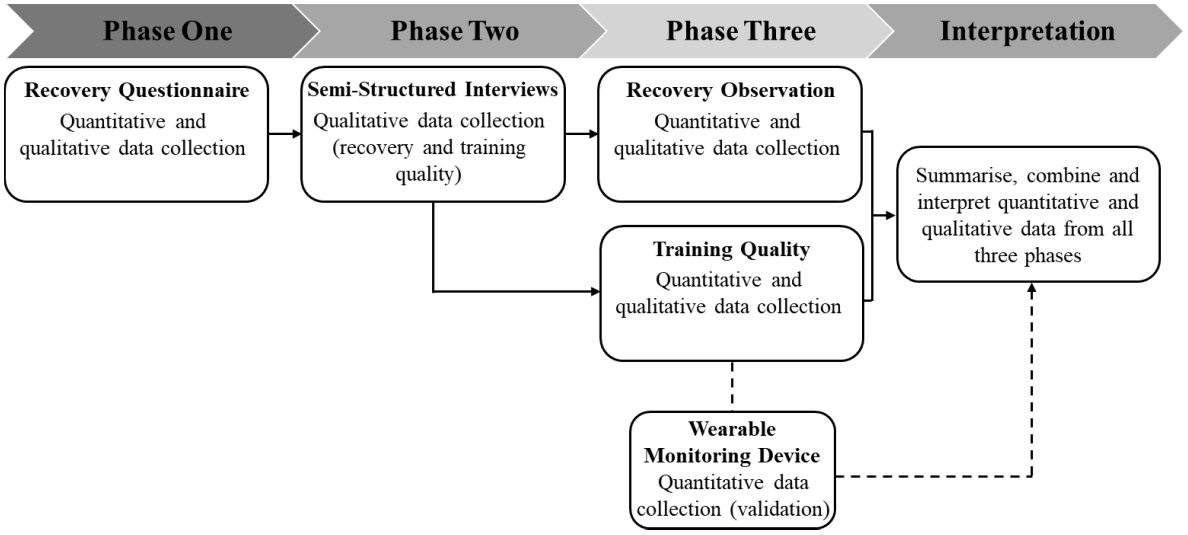

Figure 1.2 Sequential explanatory, mixed methods thesis design.

CHAPTER 2 LITERATURE REVIEW

2.1 INTRODUCTION

Exercise results in a complex challenge to whole-body homeostasis, with an array of acute or chronic adaptive cellular and systemic responses functioning to minimise this disruption.[27] For adaptations to occur in highly trained athletes, a sufficient training stimulus is required to elicit specific responses that improve the targeted performance capacities.[2] Given most training-induced adaptations occur during the recovery phase,[6] it is recommended that recovery is systematically incorporated into training programs.[7] This recovery process in athletes is multifaceted, time-dependant, and considered an important component in achieving optimal performance.[7,8]

The interplay between training periods matched with adequate recovery results in a super-compensation effect, where an athlete might exhibit enhanced performance.[9] However, increased fatigue or soreness can manifest with inadequate recovery, and a plateau or reduction in training capacities (i.e., training intensity and load) may result.[6,11] A subsequent altered adaptive response could transpire, potentially leading to undesired training outcomes.[6] Fatigue can be characterised as either perceived fatigability (i.e., changes to psychological, or homeostatic state, or both), or performance fatigability (i.e., changes to contractile function, or muscle activation, or both), with the severity and type of fatigue dependent upon exercise duration and intensity.[28] If training and recovery coupling is insufficient, fatigue increases, and the athlete's ability to achieve the desired outcomes of the training session (i.e., training quality) is continuously impaired, reduced performance capacity may manifest. Inclusion of recovery strategies can support the maintenance of training quality and training related outcomes by minimising soreness and fatigue, and reducing prolonged homeostatic

disruption.[10] This interplay between training and recovery represents the adaptation process, commonly known as the general adaptation syndrome (GAS).[29] This model is underpinned by three stages including alarm (i.e., stress response to the stimulus), resistance (i.e., processes used to resolve the stress), and the exhaustion stage (i.e., when the stressor is not removed and resistance is ineffective). Cunanan et al.[29] have adapted the GAS model to include phases of training load application and the training response, highlighting the need for adequate application of the training stressor frequency, magnitude, and duration, in addition to sufficient inclusion of recovery time and strategies (Figure 2.1).

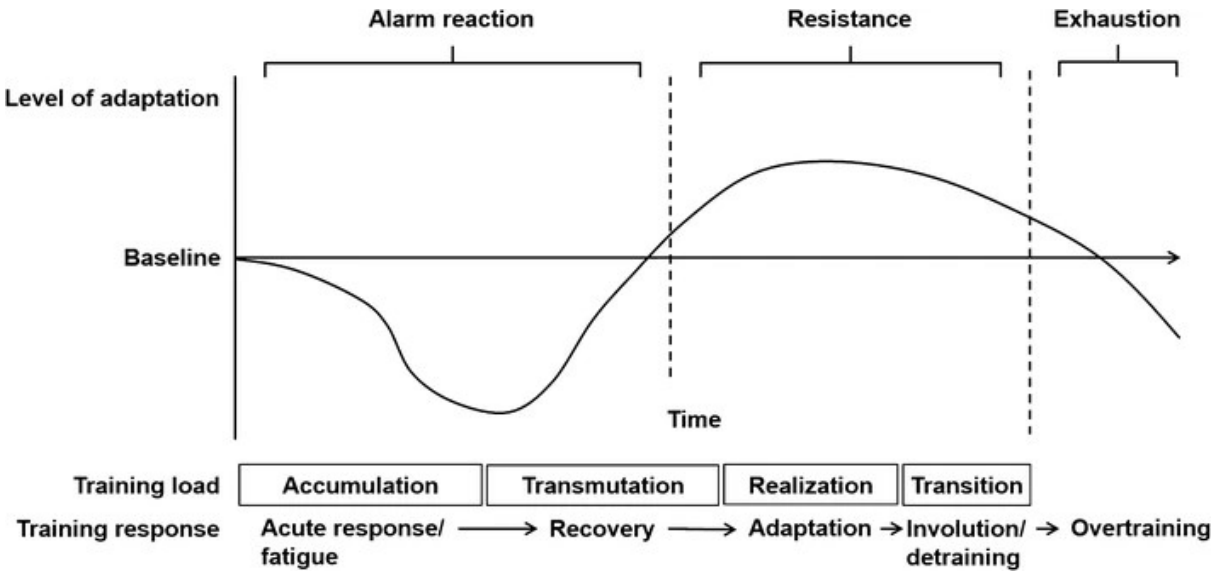

Figure 2.1 Training load and training response matched to the General Adaptation Syndrome model, representing the application of an exercise stressor and the body's natural level of adaptation. From Cunanan et al.[29]

To hasten recovery, post-exercise strategies can be employed to restore physiological and psychological capacities.[7,8] Recovery strategies can minimise the time taken to recuperate between successive exercise bouts via allostatic balance (i.e., attainment of stability through change via physiological processes that support homeostasis).[8,30] An array of recovery

activities are available to athletes, with common modalities including active recovery, stretching, massage, compression garments, and hydrotherapy.[15] Athletes, coaches and sport science practitioners must consider how to integrate these strategies to maintain training quality.

Previous research highlights the importance of recovery in the training and adaptation process,[5,6,11] however its relationship with training quality has not been specifically addressed. Instead, previous reviews allude to this relationship, by which increased fatigue might influence training quality.[10,31] Therefore, the purpose of this review is to understand how recovery can maintain, or improve aspects of training quality. This review will primarily focus on the physical recovery interventions used immediately post-exercise. A second purpose, is to highlight practical considerations for athletes, coaches and sport science practitioners when deciding on the inclusion of post-exercise recovery strategies in training.

2.1.1 Evidence-Based Practice in Recovery and Training Quality Research

Within medicine, evidence-based practice embraces a patient-centred approach, in which clinicians explicitly use best evidence to inform the decision-making process.[32] Fundamentally, evidence-based medicine involves the integration of clinical expertise, patient values and best available clinical evidence.[33] The application of evidence-based practice within sport science is described as the integration of coaching expertise, athlete values and best available research evidence.[34] To improve application to athletes and coaches, it is imperative sport science research follows such scientific processes when attempting to define and implement new practices or interventions. It is additionally important sport science practitioners consider the research questions that arise within the field from key stakeholders (i.e., athletes and coaches).[34] The use of evidence-based practice within high performance sport could enhance training and performance outcomes, and reduce training errors via inclusion of athletes and coaches knowledge, and preferences in the decision-making process.[34] Through evidence-

based research, the concept of training quality arose as a measure of training effectiveness, which could be a better, all-encompassing way to assess training. To further understand the relationship between training quality and recovery, future research studies must account for the values and experiences of athletes and coaches, through use of this evidence-based practice model.

2.2 TRAINING AND RECOVERY PERIODISATION

2.2.1 Training Periodisation

Training periodisation refers to the systematic manipulation of load and recovery to improve performance outcomes.[10] The stimulus applied through a single exercise session disrupts homeostasis, by which a myriad of acute and adaptive, cellular and systemic responses occur in an attempt to minimise this disturbance.[4,27] The cumulative effect of these adaptive responses over time with repeated exercise sessions (i.e., training) can result in improved performances in subsequent exercise bouts.[1] Periodisation describes plans with a predetermined, sequential chain of specifically focussed training periods.[35] However, this commonly involved the establishment of fitness adaptations in a successive order (i.e., strength before power), and impractical time frames, progressions and training structures.[35] Presently, the variation in targeted capacities, training stimuli, and load appear to be important in promoting adaptation and performance.[35]

A variety of periodisation approaches can be employed to provide appropriate training stimuli, with two common examples including tradition and block perdiodisation. Traditional periodisation methods involve the periodic application (e.g., macrocycle; several months, with specified phases often beginning with generalised preparation) of repeated training units.[36] This approach to periodisation is now recognised as limited, due to the training stimulus and mixed training methods being insufficient to promote ongoing developments, nor does it enable

multiple peak performances across a competitive season.[36] Conversely, block periodisation divides training into shorter periods of 1-4 weeks to improve a select few abilities (e.g., maximal oxygen uptake), while maintaining other capacities.[36] This method reduces training volumes, yet promotes physiological and technical performances.[4] However, traditional and block periodisation approaches are limited by the assumption of group-based trends and generalisation of elite athlete results, therefore individual response variability must also be considered when periodising training.[35] The concept of training periodisation has been well established,[3,35,36] however more recently the method of periodising recovery strategies has been highlighted.[10]

2.2.2 Recovery Periodisation

Appropriate inclusion and periodisation of recovery strategies into athlete training plans has been previously recognised as an important component to promote adaptation.[10] Appropriate periodisation of recovery activities can mitigate soreness and fatigue, facilitate adaptation, reduce the likelihood of a negative-stress state due to life stressors (e.g., school, study, work), and improve performance.[7,10,37,38] Recovery interventions should therefore be delivered in accordance to the individual's daily demands, with increases in stress or fatigue demanding a subsequent increase in recovery.[13],[37] If the combined load of training, competition and life stressors are greater than the individual's coping capacity, a larger degree of fatigue is likely.[7]

Recovery interventions can be strategically manipulated to elicit specific targeted outcomes. For example, use of recovery strategies can be increased immediately before competition, following long travel periods, and to manage injury or psychological stress.[10] In contrast, there are periods where recovery strategies can be deliberately reduced to increase stress and adaptive signalling, such as during general preparation phases, to maximise adaptation.[10] Conversely, athletes and coaches can prioritise recovery strategy use during specific preparation training periods, when greater emphasis is placed on skill progression, high

intensity, or high quality training sessions.[10] This complex interplay between training and recovery must be closely monitored and individualised to limit the occurrence of non-functional overreaching.[5,10]

Recovery interventions can additionally be manipulated according to the type of training stressor applied to the athlete (e.g., aerobic or resistance exercise).[1] The type of recovery strategy used will depend on the exercise modality completed and the desired adaptive response. For example, prioritising CWI after aerobic exercise may reduce exercise-induced increases in core and muscle temperatures, cardiovascular strain, and fatigue (e.g., perceived fatigability).[39] Conversely, when the goal is to promote hypertrophy, the use of CWI following resistance training may not be optimal.[40] Environmental conditions can also influence strategy selection, in which premature termination of exercise in hot conditions occurs at core temperatures of 39°C.[41] Given this large increase in core temperature resulting in an inability to sustain exercise during hot environmental conditions, it is paramount strategies are appropriately selected to enhance recovery. These examples highlight the importance of appropriate periodisation of recovery interventions.

Another important consideration for sport science practitioners when implementing recovery strategies with athletes or coaches is the benefits of the belief effect (i.e. observed effects of prior belief on performance or perceptual ratings)[42] Positive promotion and reinforcement of specific recovery strategies have demonstrated improvements in performance.[16] For example, addition of a skin cleanser to thermoneutral water immersion (placebo), as compared to thermoneutral immersion alone, resulted in enhanced recovery of maximal voluntary isometric contraction.[16] Similarly, performance was maintained in well-trained runners who believed in the benefits of compression socks for recovery, and running performance declined in those with negative or neutral perceptions of the benefits of compression socks.[17] This performance decrement illustrates the potential adverse effects of a nocebo belief. Sport science practitioners

could therefore promote belief in specific recovery strategies during education processes with athletes and coaches.[42] Further research assessing periodisation of specific recovery interventions and the influence of the belief effect is warranted.

2.2.3 Common Recovery Strategies

The following section includes a brief review of commonly used post-training active and passive recovery strategies. Strategies including nutrition and hydration, psychological strategies, ergogenic aids, analgesics, electromyostimulation, and hyperbaric oxygen therapy do not form part of this review, and have been addressed previously by Beck et al., 2015,[43] Birrer and Morgan, 2010,[44] Barnett, 2006,[11] and Bishop, Jones and Woods, 2008.[6]

Active Recovery Strategies

Active recovery is commonly used immediately post-training and encompasses submaximal movement including walking, jogging, cycling or swimming.[15] Various changes occur to enhance restoration of physiological function, some of which include accelerated reductions in tissue damage,[45-48] and improved metabolite removal. Reduced muscle soreness is a further outcome of active recovery.[45-48] Active recovery can be modified in duration, intensity, or distance. Regardless of active recovery structure, conflicting evidence exists, suggesting post-exercise active recovery may not provide beneficial changes to athlete recovery status, or performance.[11] The various protocol durations, and exercise modalities used between studies is a possible explanation for the conflicting evidence surrounding active recovery.

Passive Recovery Strategies

Sleep is highly regarded for its contribution to physiological and psychological function, and is anecdotally reported as the most important strategy to promote recovery.[49,50] The proposed theories of sleep involve restoration of the immune, endocrine, and nervous systems, and cognitive processes.[49] Consistent poor sleep quality or duration can result in reduced cognitive performance, reaction times, mood state, power production, decision-making capacity, and

performance, and an increase in fatigue.[51,52] Sleep can be improved by encouraging sleep hygiene practices (i.e., avoiding behaviours that detract from sleep, or engaging in behaviours that encourage sleep),[52] designing training schedules to reduce pre-training fatigue levels,[50] ensuring appropriate physiological and psychological recovery, minimising excessive fluid (especially caffeine or alcohol) intake before bed, and warming or cooling of the skin in cool or hot climates, respectively.[52] Strategic napping during the day is an additional strategy that can be included to "top-up" night-time sleep in athletes.[50] The impact of sleep on recovery and training is therefore an important consideration for athletes, coaches, and sport science practitioners.

Athletes routinely stretch before and post-exercise. However, the precise mechanistic effects of stretching remain unclear. Instead, post-exercise stretching has demonstrated potential reductions in muscle soreness and injury risk.[53-55] Additional recommended benefits of stretching include improvements in range of motion (ROM) and reduced muscle stiffness,[56] with the precise effects on athletic performance unknown.[53] Although stretching is routinely used by athletes to aid recovery, there is little evidence to suggest any practically significant changes to soreness, performance, or injury risk, therefore limiting justification for its use.[53,54,57] Conflicting findings within stretching research can be attributed to the low calibre of studies, and a lack of well-controlled experimental research.[53]

Common hydrotherapy methods include cold water immersion (CWI), hot water immersion (HWI) and contrast water therapy (CWT). When immersed in water, regardless of temperature, the body is met with hydrostatic pressure (i.e., a compressive force) which causes fluid displacement from the extremities to the central cavity.[58-60] Central and peripheral fluid displacement can enhance recovery through increased substrate translocation and transport, increased cardiac output, reduced peripheral resistance, and removal of waste products.[58-60] A reduction in perceived fatigue is also possible as a result of this fluid displacement.[58-60] The

additional effects of water temperature can further alter the physiological response to water immersion.

The recovery process is reportedly enhanced by CWI, through various physiological mechanisms consequently improving performance.[60] For example, reductions in core temperature, muscle oedema, and increased metabolite removal occur via capillary vasoconstriction.[61] CWI additionally reduces heart rate (HR) and subsequently cardiac output through increased arterial blood pressure and peripheral resistance, following redirection of blood flow from the periphery.[60] As a result, athletes routinely use CWI[59] to reduce DOMS,[61,62] core temperature,[63] inflammation, pain, and the loss of force generating capacity.[60] These physiological responses are thought to enhance recovery processes.[61] However, inconsistent results regarding physiological or performance changes following CWI remain. Such discrepancies are attributed to methodological differences in immersion temperature, depth or time, exercise protocols, and performance measures.[64,65] The placebo effect related to CWI efficacy is an additional contributing factor to these discrepancies.[16]

Hot water immersion as a recovery strategy alone lacks sufficient empirical support.[60] For example, some of the proposed benefits of HWI include increased nutrient delivery and metabolic waste removal via enhanced cellular permeability, as a result of increased cardiac output.[60] This change in cardiac output reduces peripheral resistance to promote subcutaneous blood flow, and is stimulated by an increase in HR.[60] However, it is recommended that care is taken with HWI use as extended periods of immersion can lead to excessive cardiovascular strain and oedema. Additional caution is required for athletes with acute injuries, wounds or illness as these can be exacerbated with heat exposure.[60] Hot water immersion has also been shown to enhance psychological recovery, by which upregulation of the parasympathetic nervous system reduces anxiety, and induces a state of relaxation.[66] Previous HWI research has primarily assessed the use of heat in athlete injuries, with limited evidence surrounding its use

as a post-exercise recovery strategy.[60] Additionally, HWI research varies in the immersion temperature, outcome measures and exercise modalities assessed, making direct comparisons between studies difficult.

Contrast water therapy refers to the alternation of hot and cold water immersion. Alternating water temperature evokes cyclical peripheral vasodilation and vasoconstriction producing a vaso-pumping action, increasing metabolite translocation and removal.[60] Consequently, reductions in muscle spasm, inflammation, oedema and DOMS have been observed.[60] Increased ROM and altered muscle temperature and blood flow are additional outcomes of CWT.[67] In conjunction with previous hydrotherapy techniques, the beneficial effects of CWT on physiological variables or performance outcomes are inconsistent. Differing immersion temperatures and time, number of alternating cycles, and outcome measures are potential explanations for these discrepancies.[12,67]

The proposed mechanisms of massage lack empirical support to suggest any physiological or performance benefits.[68-70] Regeneration of psychological functioning and mood, and decreases in perceptions of fatigue are the primary massage benefits.[71,72] Athletes anecdotally report relaxation and improved psychological functioning with massage, however these benefits do not always correlate with enhanced recovery or subsequent performance.[70] Examples of proposed physiological benefits of massage include increased muscular blood flow,[69,73] blood lactate (BLa) clearance,[73-75] and enhanced neural pathway messaging,[76] however such mechanisms are yet to be scientifically confirmed. Moreover, improvements in ROM, restoration of force generating capacity,[77] performance,[70,73,74] or reductions in DOMS, have not been previously established.[77,78] The inconsistent relative effects of massage can be attributed to a lack of experimental control, excluding a control group, or small sample sizes.[76] Matched control cross-over research is required to definitively determine the applicability and mechanisms underpinning massage to enable appropriate prescription.

Compression encompasses the use of garments (e.g., tights, tops, socks), or dynamic compression devices including peristaltic pulse dynamic (PPDC) and intermittent sequential pneumatic compression (ISPC). Traditionally, compression garments and devices are used within the clinical setting to treat numerous circulatory pathologies (e.g., deep vein thrombosis, venous ulcers, lymphedema).[79,80] Theoretically, compression creates an external pressure gradient which optimises circulation and reduces oedema.[81] Within the sporting context, compression garments are regularly used to promote peripheral blood flow redistribution by aiding venous return and arterial perfusion.[81,82] This redistribution is thought to enhance musculature restoration, nutrient delivery and metabolite removal (e.g., creatine kinase, BLa).[83,84] Improved end diastolic filling, stroke volume and cardiac output are further proposed physiological benefits of compression, however evidence supporting these claims is equivocal.[85] Furthermore, compression garments are reported to reduce DOMS associated with intense exercise,[81] with a beneficial trend for performance improvements following resistance and endurance-based exercise.[85] Discrepancies surrounding compression garment benefits are likely due to variations in study populations, exercise modality assessed, and performance outcome measures.[83]

Compressive devices comprise a boot or glove-like sleeve consisting of 4-5 separate air bladder compartments.[86] The PPDC process involves distal to proximal rhythmic application of circumferential peristaltic pressure.[87] Similarly, ISPC involves progressive inflation of each compartment within the sleeve from distal to proximal, before complete deflation occurs and the process is repeated.[82] The proposed physiological and psychological benefits of dynamic compression are equivalent to those of compression garments. Dynamic compression may reduce perceived muscle soreness,[81,88] allowing athletes to continue to train and compete at the desired level. Although the performance effects of both PPDC and ISPC remain unclear, studies have demonstrated improvements in ROM,[88] and maintenance of vertical jump

performance with ISPC.[86] However, previous studies reported no influence on subsequent high intensity anaerobic cycling,[82,89] sprint and agility tests,[81] or resistance-based performance.[90] Given the limited research into dynamic compression within the sporting context, future studies into recovery and performance improvements following use are essential.

Few studies have investigated the effectiveness of recovery strategies in accordance with how athletes and coaches currently use, or prescribe recovery. Therefore, in line with the evidence-based best practice model, it is imperative additional, well-controlled research studies are investigated that assess the efficacy of the aforementioned recovery strategies to enhance mechanistic, and training or performance outcomes following exercise. Moreover, further research into the long-term effects of post-exercise recovery strategies on training quality outcomes are required.

2.3 TRAINING QUALITY

Despite being common in the training vernacular for coaches and athletes, the concept of training quality has not previously been defined. Here, this construct is defined as an athlete's capacity to complete a training session to the desired level. Training quality might include the various constructs of physical, technical, mental, emotional, or tactical aspects, which are anecdotally recognised as important in the training process.

When determining the quality of an athlete's training session, it is important to consider the ability to achieve the prescribed outcomes from the primary training goals. Various objective or subjective load monitoring tools can inform coaches and sport scientists of the athlete's training achievements. Measures of training load are typically categorised as either internal (i.e., relative psychophysiological stress), or external load (i.e., independent objective assessment of work completed).[20] Common objective measures of internal load include HR

and BLa.[91] Subjective internal load tools include assessment of Rating of Perceived Exertion (RPE), which is commonly used to quantify the athlete's psychobiological stress resultant from exercise.[91] In contrast, examples of external load monitoring may involve assessment of distance, speed, power output, and acceleration, through use of devices, such as global position systems (GPS) and power meters.[20]

Objective assessments of load are currently used as surrogate indicators of training quality. These measures such as HR, distance, or speed commonly provide insight to the physical quality (i.e., intensity and duration) of an athlete's training session. For example, sport science practitioners often report planned against actual training loads (or intensities) completed by an athlete, to quantify if the prescribed distance and target intensity of a given training session were achieved. However, training quality is not limited to measures of intensity or duration, and it may be more appropriately assessed subjectively by those with contextual understanding of the training demands. Moreover, for overall sporting performance the tactical, technical and mental aspects are equally as important within a training session. Yet, there remains no current method to determine an athlete's perceived quality of training. Indeed, it may be that training quality is assessed via observation of an athlete's training, and direct comparison to the goal of the session and their training history. At present, the assessment of training quality has not been directly addressed, with no validated tools available. Therefore, future studies are required to not only further define the construct of training quality, but to also produce simple monitoring tools to assess quality. Quantifying the quality of a session may be important to further appreciate the complex interplay between factors which impact an athletes training capacity.

2.3.1 Relationship between Training Quality and Recovery

Inclusion of acute recovery strategies (i.e., between sessions) could enhance training quality outcomes, including the physical (e.g., target sets and repetitions), technical (e.g., movement efficiency), or mental (e.g., motivation) constructs. As presented in the conceptual model in

Figure 2.2, this improvement or maintenance of training quality could augment an athlete's training output, and the ensuing training stimulus. This training output and stimulus will ultimately result in an array of training-induced adaptations, which the athlete must recover from to maintain homeostatic balance. The training output therefore dictates the type of recovery intervention required to combat the specific deficits attained during the session (e.g., soreness, fatigue). Use of targeted and individualised strategies could subsequently lead to superior recovery and training quality (Figure 2.2).

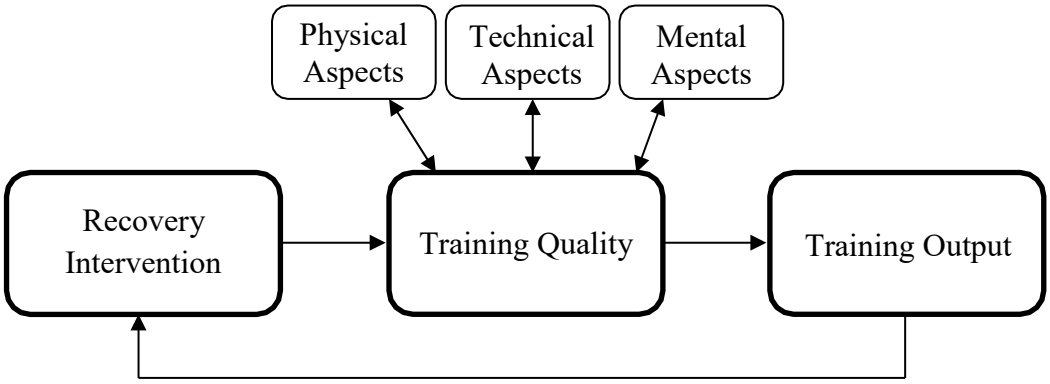

Figure 2.2 Conceptual relationships between use of recovery strategies, and their potential effect on training quality, and subsequently the athlete's training output.

Adequate education of potential acute recovery benefits to maintain training quality could increase the likelihood of strategy adoption by athletes and coaches. As previously highlighted, providing a positive belief effect enhances an athlete's recovery,[16,17] which could potentially lead to improved physical, technical and mental training quality (Figure 2.3). On the contrary, if an athlete experiences no change in recovery (or training outcomes) following use of a specific strategy, it is possible they will maintain a negative belief which may become detrimental to their recovery status, and therefore training quality. The proposed relationship between belief effect, recovery status, and training quality could further be evidenced through

a negative belief effect, in which a negative belief in a strategy may not be detrimental to physical or technical recovery and training quality (i.e., physiological or performance benefits). However, the athlete's mental status could be negatively affected through use of a strategy they do not enjoy or perceive as beneficial (Figure 2.3). Likewise, a positive belief in a recovery strategy may not result in enhanced recovery, where the athlete may perceive they are recovered and ready to train, however they have not recovered physically, therefore affecting their training capacity (Figure 2.3). The belief effect and individual variation (i.e., dramatic changes that occur as a result of age, culture, and as a function of context),[92] are therefore important considerations when programming recovery strategies for an athlete to maintain training quality.

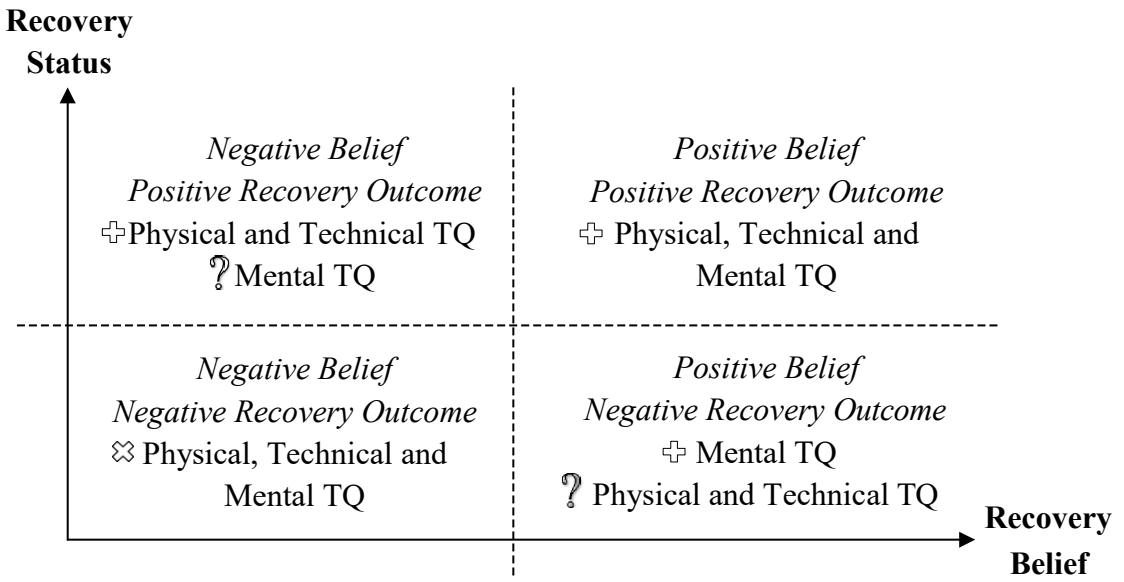

Figure 2.3 Proposed interaction between an athlete or coach's belief effect for a specific recovery strategy, and an athlete's possible recovery status/outcome. TQ – Training Quality, ? – effect unknown, ✣ – positive effect, ⛒ – negative effect.

Table 2.1 depicts the proposed relationship between specific recovery strategies, and how these might be used to enhance aspects of training quality, specifically physical, technical and mental quality. Additionally, approaches for integrating these strategies across different training phases and session types is described. Exercise modality is described as anaerobic exercise (i.e., short or intermediate duration), aerobic exercise (i.e., long duration), or resistance exercise (i.e., strength, power, or velocity), and is applicable for either individual or team-based sports. It is likely the type of strategy used will be an important factor to assist recovery of specific training quality constructs.

Table 2.1 Proposed relationship between recovery strategies and training quality in relation to exercise modality and periodisation phase.

Recovery Strategy	Proposed Impact on Training Quality			^Exercise Modality and Associated Periodisation Phase
	Physical	**Technical**	**Mental**	
Active Recovery	*HR, respiratory rate, blood flow ↓DOMS, lactate removal ↑Heat dissipation	↓DOMS	↓Perceived fatigue	• Aerobic and anaerobic exercise (general preparation, specific preparation, taper, competition)
Compression	↓Oedema, DOMS ↑Blood flow, venous return *metabolite removal (i.e., CK, BLa)	↑Movement efficiency ↓DOMS	↑Perceived recovery ↓Perceived fatigue	• Aerobic, anaerobic, and resistance exercise (general preparation, specific preparation, taper, competition)
CWI	↓DOMS, HR, core/muscle/skin temperature, oedema, inflammation ↑Performance, capillary vasoconstriction	↑Movement efficiency ↓DOMS	↓Mood disturbances ↑Perceived recovery	• Aerobic exercise (specific preparation, taper, competition) • Anaerobic and resistance exercise (taper)
CWT	↑Blood flow, metabolite removal, performance	↑Movement efficiency, ROM ↓DOMS	↓Mood disturbances ↑Perceived recovery	• Aerobic and anaerobic exercise (specific preparation, taper, competition) • Resistance exercise (specific preparation)
Massage	↑ROM ↔Blood flow, DOMS, metabolite removal, performance	↔Force generating capacity	↑Perceived recovery ↓Perceived fatigue	• Aerobic and anaerobic exercise (specific preparation, taper, competition) • Resistance exercise (specific preparation, taper, competition)
Sleep	↑Physiological function, performance ↓Fatigue, DOMS	↑Reaction time, consolidation of processes and skills ↓Errors, DOMS	↑Neurocognitive function, decision-making capacity, mood, motivation	• Aerobic, anaerobic, and resistance exercise (general preparation, specific preparation, taper, competition)
Stretching	↑Muscle relaxation ↓Risk of injury	↑ROM, flexibility *DOMS		• Aerobic and anaerobic exercise (general preparation, specific preparation, taper, competition)

↓ = reduction; ↑ = increased; ↔ = no change; * = research effects are unclear meaning proposed effects on training quality are unknown; HR = heart rate; DOMS = delayed onset muscle soreness; ROM = range of motion; CK = creatine kinase; BLa = blood lactate; ^ = consideration must be given to the sport, individual and environmental demands.

Recovery Strategies to Enhance Physical Training Quality

Physical training quality refers to the physical attributes required to achieve training outcomes, including sufficient aerobic or anaerobic capacities, ability to meet target outcomes such as set distances or repetitions, or high training intensities. Coaches currently assess physical training capacities through objective measures including distance covered, HR, speed, and via subjective assessment through use of RPE to determine an athlete's perceived effort.[20] However, these methods primarily provide indication of session intensity, and fail to identify the perceived physical quality of an athlete's session.

The suggested physical benefits of recovery strategies include increased metabolite removal, altered skin, core and muscle temperature, reduced DOMS, and improved performance.[15] DOMS is one potential contributing factor to the reduction in physical training quality, by which an athlete may experience physiological and performance (e.g., strength, power, force) deficits. This benefit has been reported in several studies where reductions in DOMS has been demonstrated with the use of CWI or CWT.[63,93] Moreover, CWI minimised the fitness and performance (e.g., acceleration, agility, vertical jump, flexibility) decrements induced by repetitive basketball matches, as compared to stretching and compression garments.[94] Inclusion of appropriate recovery strategies between subsequent sessions could therefore enhance physical training quality, with further examination of this relationship warranted.

Recovery Strategies to Enhance Technical Training Quality

Technical training quality includes the skills required during training. The level of emphasis placed on technical quality will differ with various sporting demands. Tennis is one example where an athlete requires considerable technical expertise to excel in their sport. Stroke velocity, serving proficiency and quality, position of ball toss and smoothness of action, are examples of common skills assessed during tennis play.[95,96] Within soccer, technical performance, with technical components including pass accuracy, shots on target, and

successful dribbles, are a strong predictor of successful performance.[97,98] Swimming is an additional sport where an athlete's skill, specifically in relation to propulsion efficiency, is a key contributing factor to swimming performance.[18] Anecdotally, there is a large emphasis on the technical aspects of sports, however there remains no direct assessment of perceived technical training quality.

Previous research has reported that adequate recovery is imperative to skill progression and maintenance.[99] Recovery strategies may enhance skill consolidation and technical training quality through rest and relaxation, in which consolidation processes might occur with sufficient time and during sleep.[100] It is possible that the use of hydrotherapy (e.g., CWI or CWT) could enhance technical training quality through reductions in DOMS,[101] and increased movement efficiency. If recovery strategies can be appropriately used to reduce soreness and fatigue, an athlete's ability to complete technical skills through a full range of movement without, or with reduced pain is likely to be increased. Additionally, reduced soreness and fatigue could increase the likelihood of producing sufficient force, and completing movements with appropriate technique. However, there is currently no empirical evidence to support these suggestions, therefore further investigation into the potential beneficial effects of recovery strategies on technical training quality is required.

Recovery Strategies to Enhance Mental Training Quality

Mental training quality might reflect an athlete's motivation, engagement, attention, or focus demonstrated during a training session. Currently, there are no measures to identify an athlete's mental engagement with training, and instead assessment tools often examine an athlete's recovery status or mood state surrounding training.[8] The inclusion of recovery sessions into an athlete's seasonal plan could increase engagement and motivation, with appropriate planning potentially minimising the risk of extra hours being devoted to training.[4] Improving athlete motivation and minimising the risk of distracted athletes through adequate recovery, could have

subsequent beneficial effects on physical and technical training quality outcomes. For example, a well-recovered and engaged athlete is more likely to consistently train at greater intensities, and maintain technical proficiencies across multiple sessions.

Psychological regeneration through recovery strategy use could promote mental training quality via increased attention and mood state. Research investigating the use of strategies to improve psychological recovery has primarily focussed on strategy inclusion during periods of overload, in an attempt to treat athlete burnout which may contribute to demotivation.[4,72] Regular inclusion and periodisation of recovery strategies could increase an athletes ability to 'back-up' between sessions (i.e., decreased feelings of fatigue, increased perceived recovery), through maintenance of motivation (i.e., mental training quality) despite changes in training or life demands. Massage is one such strategy which athletes use on a regular basis post-exercise and between events to promote recovery.[76] Given the minimal evidence regarding the physiological benefits of massage, the proposed recovery benefits are likely solely psychological in nature.[76,102]

Sleep is another recovery strategy which might promote the maintenance of mental training quality. For example, during sleep restriction, increased psychological fatigue and an adverse neurocognitive state arise, subsequently negatively affecting activities which require high levels of motivation or decision-making capacities, such as those experienced in training.[49] However, further empirical evidence is required to substantiate these concepts. Nevertheless, if an athlete prioritises sleep, it is possible increased motivation and mental engagement may result. Use of flotation rest (i.e., floatation tanks) is an additional, relatively unexplored recovery strategy that could enhance mental training quality through upregulation of parasympathetic nervous system activity, and consequently perceived increases in well-being, and decreases in stress.[103] Therefore, future studies should investigate how specific recovery strategies could maintain or improve mental training quality.

2.4 SWIMMING TRAINING

Swimming is a competitive sport requiring well developed physical capacities and considerable technical proficiency.[18] Pool race distances range from 50-1500-m in four different strokes; freestyle, backstroke, breaststroke and butterfly.[18]

A swimmer's performance is directly related to their propulsive force generating capacity to overcome the effects of water resistance or drag.[18] Technical ability, swim velocity, race intensity, and amount of drag influences the energy requirements for each distance and stroke.[18] These energy requirements are met via contributions from the adenosine triphosphate phosphocreatine, anaerobic glycolysis and aerobic glycolysis systems. Depletion of these systems can occur during training and competition, subsequently inducing fatigue.[104] Additional mechanisms underpinning fatigue include increased metabolite accumulation, neuromuscular, or cognitive fatigue.[104]

Among other purposes, such as skill acquisition, training aims to maximise individual physiological adaptations through application of a training stimulus.[105] Sprint (i.e., 50 and 100-m) and middle-distance (i.e., 200 and 400-m) swimmers often complete five to eight training sessions per week, and one to two gym sessions,[106] across approximately 44-48 weeks per year.[107] Training often incorporates four main phases including build-up, specialty, taper and post-competition.[106] Across the summer and winter seasons swimmers will spend approximately 12 weeks in build-up, seven in specialty, and three in taper and post-competition phases.[106] A gradual decrease in total distance swum and an increase in session intensity is seen during the transition from the build-up to post-competition phase.

Conjecture still exists as to the most appropriate structure of swim training, specifically regarding the combination of high volume low intensity, or low volume high intensity training.[19,108,109] Previous research has demonstrated beneficial effects of low volume high

intensity training on endurance capacity in sprint and middle distance swimmers,[108] whereas other studies have suggested high volume low intensity training could benefit shorter distance swimmers through improved training tolerance and skill refinement.[109] Moreover, swimmers who completed two training sessions per day, as compared with one, demonstrated slower speeds in sprint events, yet faster swim times in longer events.[110] Regardless of the training structure, the long-term periodisation of training is essential to create a system which can detect potential threats and opportunities to optimise performance outcomes.[111] Training monitoring can be used to inform this periodisation, however the assessment of training load within swimmers remains a challenge.

There are currently very few valid and reliable measures of training load available to swimmers, coaches and sport science practitioners.[112] Distance and swim velocity are the two primary methods of prescribing external training loads, however these fail to identify the physiological stress (i.e., internal load) imposed on the swimmer.[112] HR monitoring devices have traditionally been used as objective assessments of internal load, however the technical failure of these devices increases with use in water.[113] Blood lactate profiling has been widely used to monitor training, training adaptations, and determine exercise intensities within swimmers.[114,115] However, the metabolic contributions of the various stroke types, and difficulties with field-based measurements[115] (e.g., equipment cost and access) can cause difficulties in measurement. As such, the session-RPE method (i.e., subjective rating of session intensity multiplied by session duration) is regularly used to quantify psychophysiological training responses in swimmers.[112,116] Although the session-RPE method is a valid measure of psychophysiological load, there still remains need for a valid objective assessment of training load in swimmers that can measure training distances, stroke counts, velocity, and time spent in each stroke type. Such a device and assessment of swimmer training may begin to elucidate the training demands experienced by swimmers.

2.5 CONCLUSION

Athletes regularly complete large training volumes, which if matched with insufficient recovery will potentially result in greater levels of fatigue. Anecdotally, training quality comprises a significant component of training, yet there remains no empirical definition or assessment of quality. Moreover, athletes, coaches and sport scientists can use specific recovery strategies to reduce the disruption caused by training, to assist the maintenance of training quality across subsequent sessions. However, no research exists defining this potential relationship between recovery and training quality. Future research studies are therefore required to define training quality, through use of evidence-based best practice models to understand athlete and coaches expertise, and to further understand the relationship between training quality and recovery.

Within swimming specifically, there is limited research describing the perceptions or practices of athlete recovery or training quality. Despite anecdotal reports of the nature of recovery interventions used by athletes, limited research exists investigating how swimmers specifically use recovery strategies during training and competition. Inclusion of recovery strategies could enhance a swimmer's training quality, theoretically leading to a greater training stimulus and improved training outcomes. It is therefore necessary to determine swimmers' use and perceptions of specific recovery strategies. Moreover, a simple and valid tool to assess training quality is needed, as the current objective and subjective training load monitoring tools used in swimming fail to directly assess quality.

CHAPTER 3 STUDY ONE: PERCEPTIONS AND USE OF RECOVERY STRATEGIES: DO SWIMMERS AND COACHES BELIEVE THEY ARE EFFECTIVE?

Citation: **Shell, S.J.**, Slattery, K., Clark, B., Broatch, J.R., Halson, S., Kellmann, M., & Coutts, A.J. (2019). Perceptions and use of recovery strategies: Do swimmers and coaches believe they are effective? *Journal of Sports Sciences, Accepted for Publication, DOI: 10.1080/02640414.2020.1770925.*

This study is presented as the first in a series of related studies investigating the use and perceptions of recovery strategies, and training quality. Chapter 3 aimed to firstly understand how swimmers use, and coaches prescribe, specific recovery strategies during both training and competition. The secondary purpose of Chapter 3 was to describe the reasons for, and barriers to strategy use, as perceived by swimmers and their coaches.

Declaration for Thesis Chapter 3

Declaration by candidate

In the case of Chapter 3 the nature and extent of my contribution to the work was the following:

Nature of contribution	Extent of contribution (%)
Study design, data collection and analysis, interpretation of results, and study write up	65

The following co-authors contributed to the work.

Name	Nature of contribution	Extent of contribution (%)
Katie Slattery	Assistance with study design, interpretation of results and proof reading of drafts	7
Brad Clark	Assistance with study design, analysis and interpretation of results and proof reading of drafts	7
James Broatch	Assistance with interpretation of results and proof reading of drafts	5
Shona Halson	Assistance with study design, interpretation of results and proof reading of drafts	4
Michael Kellmann	Assistance with study design, interpretation of results and proof reading of drafts	4
Aaron Coutts	Assistance with study design, interpretation of results and proof reading of drafts	8

Candidate's Signature	Production Note: Signature removed prior to publication.	Date 07/05/2020

Declaration by co-authors

The undersigned hereby certify that:

(1) the above declaration correctly reflects the nature and extent of the candidate's contribution to this work, and the nature of the contribution of each of the co-authors.
(2) they meet the criteria for authorship in that they have participated in the conception, execution, or interpretation, of at least that part of the publication in their field of expertise;
(3) they take public responsibility for their part of the publication, except for the responsible author who accepts overall responsibility for the publication;
(4) there are no other authors of the publication according to these criteria;
(5) potential conflicts of interest have been disclosed to (a) granting bodies, (b) the editor or publisher of journals or other publications, and (c) the head of the responsible academic unit; and
(6) the original data are stored at the following location(s) and will be held for at least five years from the date indicated below:

Location(s)	University of Technology Sydney, Moore Park, NSW Australian Institute of Sport, Bruce, ACT	
Co-author Signature Number	**Co-author's Signatures**	**Date**
Signature 1	Production Note: Signature removed prior to publication.	07/05/20
Signature 2	Production Note: Signature removed prior to publication.	07/05/20
Signature 3	Production Note: Signature removed prior to publication.	07/05/20
Signature 4	Production Note: Signature removed prior to publication.	07/05/20
Signature 5	Production Note: Signature removed prior to publication.	07/05/20
Signature 6	Production Note: Signature removed prior to publication.	07/05/20

3.1 ABSTRACT

This study aimed to investigate swimmer's use and coach prescription of recovery strategies during training and competition, while examining perceived challenges, barriers, and beliefs in the importance of their effectiveness. A mixed-methods sequential explanatory design was implemented. Thirty-seven male and forty-five female sub-elite to elite swimmers (age 18 ± 3 y), and four male and six female coaches (age 40 ± 9 y), completed an online, 78-item recovery strategy survey. Swimmers and coaches responded to questions regarding when, why and how they used recovery strategies, perceived challenges and barriers to strategy inclusion during training and competition. Data were coded and analysed thematically. Fisher's Exact Test was conducted on 5-point Likert scale responses. Most recovery strategies were used and prescribed more during competition. Swimmers reported active recovery as the most effective recovery strategy (44%), whereas coaches rated sleep or napping (40%). Swimmers and coaches, perceived most recovery strategies to be more effective and important during competition than in training. Swimmers used, and coaches prescribed, recovery strategies more during competition, highlighting the discrepancies in use between training and competition. Targeted education programs should enhance athletes and coach's recovery knowledge and practical application of strategies, while accounting for individual sport and life demands.

Keywords

Post-exercise recovery, swimming, belief effect, hydrotherapy, cold water immersion

Shell, S.J., Slattery, K., Clark, B., Broatch, J.R., Halson, S., Kellmann, M., & Coutts, A.J. (2019). Perceptions and use of recovery strategies: Do swimmers and coaches believe they are effective? *Journal of Sports Sciences*, Accepted for Publication, DOI: 10.1080/02640414.2020.1770925.

CHAPTER 4 STUDY TWO: SELF-REPORT V PRACTICE: COMPARISONS BETWEEN SWIMMERS' REPORTED AND OBSERVED RECOVERY STRATEGY USE.

Citation: **Shell, S.J.**, Clark, B., Slattery, K., Broatch, J.R., Halson, S., & Coutts, A.J. (2019). Self-Report v Practice: Comparisons between swimmers' reported and observed recovery strategy use. *Journal of Science and Medicine in Sport, Under Review.*

The main finding from Chapter 3 was that swimmers use, and coaches prescribe, more recovery strategies during competition, as compared to training. Additionally, swimmer's and coaches perceived recovery strategies to be more effective and important in competition, as compared to training. Lastly, Chapter 3 identified the two primary barriers for completing recovery sessions included a lack of time, and not having access to equipment or resources, within both training and competition. It is therefore conceivable that the environment surrounding the swimmers may not be conducive to completing recovery. Subsequently, the purpose of Chapter 4 was to further understand how swimmers use specific recovery strategies during training and competition. To achieve this, athlete observations were implemented for comparison with the swimmer's self-reported recovery strategy use.

Declaration for Thesis Chapter 4

Declaration by candidate

In the case of Chapter 4 the nature and extent of my contribution to the work was the following:

Nature of contribution	Extent of contribution (%)
Study design, data collection and analysis, interpretation of results, and study write up	65

The following co-authors contributed to the work.

Name	Nature of contribution	Extent of contribution (%)
Katie Slattery	Assistance with study design, interpretation of results and proof reading of drafts	6.5
Brad Clark	Assistance with study design, analysis and interpretation of results and proof reading of drafts	6.5
James Broatch	Assistance with study design, data collection, analysis and interpretation of results and proof reading of drafts	6.5
Shona Halson	Assistance with study design, interpretation of results and proof reading of drafts	5.5
Aaron Coutts	Assistance with study design, interpretation of results and proof reading of drafts	10

Candidate's Signature	Production Note: Signature removed prior to publication.	Date 07/05/2020

Declaration by co-authors

The undersigned hereby certify that:

(1) the above declaration correctly reflects the nature and extent of the candidate's contribution to this work, and the nature of the contribution of each of the co-authors.
(2) they meet the criteria for authorship in that they have participated in the conception, execution, or interpretation, of at least that part of the publication in their field of expertise;
(3) they take public responsibility for their part of the publication, except for the responsible author who accepts overall responsibility for the publication;
(4) there are no other authors of the publication according to these criteria;
(5) potential conflicts of interest have been disclosed to (a) granting bodies, (b) the editor or publisher of journals or other publications, and (c) the head of the responsible academic unit; and
(6) the original data are stored at the following location(s) and will be held for at least five years from the date indicated below:

Location(s)	University of Technology Sydney, Moore Park, NSW Australian Institute of Sport, Bruce, ACT	
Co-author Signature Number	**Co-author's Signatures**	**Date**
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Signature 3	Production Note: Signature removed prior to publication.	07/05/20
Signature 4	Production Note: Signature removed prior to publication.	07/05/20
Signature 5	Production Note: Signature removed prior to publication.	07/05/20

4.1 ABSTRACT

Objectives: This study aimed to determine differences between self-reported and observed recovery strategy use during training and competition.

Design: A mixed-methods sequential explanatory design was implemented for the current investigation.

Methods: Eleven female (22 ± 2 y, 1 sub-elite, 2 elite) and male (23 ± 4 y, 4 sub-elite, 4 elite) swimmers participated in this study. A recovery survey, athlete observation, and 20-30 min semi-structured interviews were implemented to examine the use of post-exercise recovery strategies in the swimmer's training and competitive environments. Survey responses, interview transcriptions, and observational field notes were stored, analysed, and organised thematically.

Results: Swimmers self-reported greater strategy use, as compared to observed recovery strategy use. A variety of recovery strategies used across training and competition. A large proportion of swimmers reported using self-massage during training and competition (91% and 100%, respectively), yet only two out of 11 swimmers were observed using self-massage in training. Active recovery was the only strategy where self-reported and observed activity were comparable. Recovering according to 'feel' was a common theme evident across most swimmers.

Conclusions: Athlete observations revealed swimmers would exaggerate their use of recovery strategies in training and competition when self-reporting. Swimmers self-select recovery strategies on-the-day according to how they 'feel' mentally, emotionally, and physically. As such, an iterative approach to recovery programming may help to individualise strategy use

and enhance recovery status. Qualitative methodologies provide a multi-dimensional approach to understanding athlete recovery strategy use and perceptions.

Keywords: Cold water immersion, compression garments, self-regulation, periodisation, nap, soreness

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Shell, S.J., Clark, B., Slattery, K., Broatch, J.R., Halson, S., & Coutts, A.J. (2019). Self-Report v Practice: Comparisons between swimmers' reported and observed recovery strategy use. *Journal of Science and Medicine in Sport*, Under Review.

CHAPTER 5 STUDY THREE: DEVELOPMENT AND VALIDITY OF THE SUBJECTIVE TRAINING QUALITY SCALE.

Citation: **Shell, S.J.**, Slattery, K., Clark, B., Broatch, J.R., Halson, S., & Coutts, A.J. (2019). Development and Validity of the Subjective Training Quality scale. *International Journal of Sport Physiology and Performance, Under Review.*

Chapter 4 concluded that swimmers' self-reported and observed recovery strategy use vary greatly, in which athlete observations revealed swimmers would exaggerate strategy use. During the semi-structured interviews (Chapter 4), the swimmers identified the importance of recovery strategies to maintain training quality and competitive performances. The semi-structured interviews from Chapter 4 were additionally used to probe swimmers regarding this training quality concept. Training quality is an important consideration in the assessment of training effectiveness, and is commonly used anecdotally to describe whether or not the outcomes of a training session were achieved. Given athletic outcomes are closely related to recovery, it is possible an athlete's training quality is also associated to their perceived recovery status. Chapter 5 therefore aimed to understand how athlete's define the concept of training quality, and subsequently develop a subjective monitoring tool that can be used to assess training quality within the daily training environment.

Declaration for Thesis Chapter 5

Declaration by candidate

In the case of Chapter 5 the nature and extent of my contribution to the work was the following:

Nature of contribution	Extent of contribution (%)
Study design, data collection and analysis, interpretation of results, and study write up	65

The following co-authors contributed to the work.

Name	Nature of contribution	Extent of contribution (%)
Katie Slattery	Assistance with study design, interpretation of results and proof reading of drafts	6.5
Brad Clark	Assistance with study design, analysis and interpretation of results and proof reading of drafts	6.5
James Broatch	Assistance with study design, data collection, analysis and interpretation of results and proof reading of drafts	6.5
Shona Halson	Assistance with study design, interpretation of results and proof reading of drafts	5.5
Aaron Coutts	Assistance with study design, interpretation of results and proof reading of drafts	10

Candidate's Signature	Production Note: Signature removed prior to publication.	Date 07/05/2020

Declaration by co-authors

The undersigned hereby certify that:

(1) the above declaration correctly reflects the nature and extent of the candidate's contribution to this work, and the nature of the contribution of each of the co-authors.
(2) they meet the criteria for authorship in that they have participated in the conception, execution, or interpretation, of at least that part of the publication in their field of expertise;
(3) they take public responsibility for their part of the publication, except for the responsible author who accepts overall responsibility for the publication;
(4) there are no other authors of the publication according to these criteria;
(5) potential conflicts of interest have been disclosed to (a) granting bodies, (b) the editor or publisher of journals or other publications, and (c) the head of the responsible academic unit; and
(6) the original data are stored at the following location(s) and will be held for at least five years from the date indicated below:

Location(s)	University of Technology Sydney, Moore Park, NSW Australian Institute of Sport, Bruce, ACT	
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Signature 2	Production Note: Signature removed prior to publication.	07/05/20
Signature 3	Production Note: Signature removed prior to publication.	07/05/20
Signature 4	Production Note: Signature removed prior to publication.	07/05/20
Signature 5	Production Note: Signature removed prior to publication.	07/05/20

5.1 ABSTRACT

Purpose: This study aimed to define, develop and validate a subjective scale of training quality.

Methods: Two related studies were used to define training quality (Part One), develop and validate a subjective scale (Part Two). Part One: a purposive sample of 15 sub-elite (i.e., national) to elite (i.e., international) swimmers participated in one, 20-30-min semi-structured interview. Thematic analysis established three training quality constructs; physical, technical, and mental, for inclusion in the Subjective Training Quality (STQ) scale. Part Two: 252 sub-elite to elite athletes, across eight sports completed the STQ scale. Cronbach's alpha (α) assessed internal consistency, histogram plot analysis assessed face validity, confirmatory factor analysis (CFA) compared physical, technical, mental, and RPE constructs with training quality. Root mean square error of approximation (RMSEA) and standardised root mean square residual (SRMR) evaluated CFA quality of fit.

Results: Physical, technical, and mental constructs demonstrated strong internal consistency (α=0.85) and excellent face validity. Inclusion of RPE reduced training quality internal consistency (α=0.73). CFA quality of fit was excellent (RMSEA=<0.01 "excellent", SRMR=0.00 "perfect"), and decreased with inclusion of RPE (RMSEA=0.088 "mediocre", SRMR=0.01 "good").

Conclusions: The STQ scale demonstrates excellent internal consistency and face validity, establishing capacity to monitor training quality. Inclusion of RPE reduced internal consistency and quality of fit, therefore it is inappropriate to use RPE to indicate training quality. Further investigation is required to determine how the STQ scale may interact with subjective and objective training measures, and how it could be incorporated into daily training monitoring.

Keywords: training monitoring, heart rate, internal load, objective, evidence-based, swimming

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Shell, S.J., Slattery, K., Clark, B., Broatch, J.R., Halson, S., & Coutts, A.J. (2019). Development and Validity of the Subjective Training Quality scale. International *Journal of Sport Physiology and Performance*, Under Review.

CHAPTER 6 STUDY FOUR: IS A HEAD-WORN INERTIAL SENSOR A VALID TOOL TO MONITOR SWIMMING?

Citation: **Shell, S.J.**, Clark, B., Slattery, K., Broatch, J.R., Halson, S., & Coutts, A.J. (2019). Is a head-worn inertial sensor a valid tool to monitor swimming? *Prepared as a technical report for publication in the International Journal of Sport Physiology and Performance.*

The primary finding from Chapter 5 was that training is defined by three constructs (i.e., physical, technical and mental). Additionally, Chapter 5 developed the STQ scale for the purpose of monitoring training quality in athletes. This scale demonstrated strong internal consistency and face validity results. However, additional validation of the STQ scale is required before it can be used as an assessment tool in the daily training environment. Chapter 6 initially aimed to further validate the STQ scale, by comparing ratings with an objective measure of training quality. However, the wearable device which was to be used as an objective measure of training quality, firstly required independent validation. Therefore, the final study (Study Four) presented as part of this thesis was designed to validate a head-worn inertial sensor used in training, across various swimming metrics.

Declaration for Thesis Chapter 6

Declaration by candidate

In the case of Chapter 6 the nature and extent of my contribution to the work was the following:

Nature of contribution	Extent of contribution (%)
Study design, data collection and analysis, interpretation of results, and study write up	65

The following co-authors contributed to the work.

Name	Nature of contribution	Extent of contribution (%)
Katie Slattery	Assistance with study design, interpretation of results and proof reading of drafts	6.5
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Aaron Coutts	Assistance with study design, interpretation of results and proof reading of drafts	10

Candidate's Signature	Production Note: Signature removed prior to publication.	Date 07/05/2020

Declaration by co-authors

The undersigned hereby certify that:

(1) the above declaration correctly reflects the nature and extent of the candidate's contribution to this work, and the nature of the contribution of each of the co-authors.
(2) they meet the criteria for authorship in that they have participated in the conception, execution, or interpretation, of at least that part of the publication in their field of expertise;
(3) they take public responsibility for their part of the publication, except for the responsible author who accepts overall responsibility for the publication;
(4) there are no other authors of the publication according to these criteria;
(5) potential conflicts of interest have been disclosed to (a) granting bodies, (b) the editor or publisher of journals or other publications, and (c) the head of the responsible academic unit; and
(6) the original data are stored at the following location(s) and will be held for at least five years from the date indicated below:

Location(s)	University of Technology Sydney, Moore Park, NSW Australian Institute of Sport, Bruce, ACT	
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Signature 3	Production Note: Signature removed prior to publication.	07/05/20
Signature 4	Production Note: Signature removed prior to publication.	07/05/20
Signature 5	Production Note: Signature removed prior to publication.	07/05/20

6.1 ABSTRACT

Purpose: This study aimed to independently validate a wearable inertial sensor designed to monitor training and performance metrics in swimmers.

Methods: Four male (21 ± 4 y, one national, three international) and six female (22 ± 3 y, one national, five international) swimmers completed 15 training sessions in an outdoor 50-m pool. Swimmers were fitted with a wearable device (TritonWear®, 9-axis inertial measurement unit (tri-axial accelerometer, gyroscope, and magnetometer)), placed under the swim cap on top of the occipital protuberance. Video footage was captured for each session. Absolute error, standardised effect and Pearson's correlation coefficient examined the differences and relationship between the data collection methods for total session swim distance, total stroke count, mean stroke count, and mean velocity. Fisher's exact test was used to analyse the accuracy of stroke type identification. Intra-rater video analysis reliability was calculated using log-transformed intraclass correlation coefficient and typical error as a coefficient of variation.

Results: The wearable device demonstrated consistently higher absolute errors in mean and total stroke count, and mean velocity, relative to video analysis. The device presented an overall difference of 680 ± 390-m in total swim distance across all sessions, relative to the video. Across all sessions and all strokes, the device incorrectly detected total stroke type. The device detected 76 and 14% laps of freestyle and backstroke, respectively, as compared to 54 and 7%, respectively with video analysis.

Conclusions: The wearable device investigated in this study does not accurately measure distance, stroke count, and velocity swimming metrics, or detect stroke type. Its use is therefore limited to monitor swimmers' training.

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Shell, S.J., Clark, B., Slattery, K., Broatch, J.R., Halson, S., & Coutts, A.J. (2019). Is a head-worn inertial sensor a valid tool to monitor swimming? Prepared as a technical report for publication in the International Journal of Sport Physiology and Performance.

CHAPTER 7 DISCUSSION OF THESIS

7.1 THESIS FINDINGS

The aim of this thesis was to explore the recovery strategies used by competitive swimmers, investigate the construct of training quality, and subsequently develop a training quality monitoring tool. Swimmer's recovery practices, and perceptions of training quality were examined through a series of four studies, using a sequential explanatory, mixed methods design. A mixed method approach enabled quantitative and qualitative data to be combined and compared, providing greater insight into swimmers' perceptions and practices. Previous recovery investigations have focussed on athlete strategy use (i.e., what strategies and how often), with little research into the reasons behind why athlete use, or do not use specific strategies. Application of the evidence-based best practice model (i.e., consideration given to athlete values and coaching expertise), supported deeper exploration of athlete and coach's recovery strategy perceptions, therefore expanding and advancing prior knowledge.[34] We also attempted, for the first time, to describe and assess training quality within varying cohorts of athletes. This was achieved through use of the evidence-based best practice model, where consideration was given to the key stakeholders' expertise. The following chapter presents the key themes derived from the four studies.

7.1.1 Recovery Strategy Use and Perceptions

It is currently recommended that recovery strategy use should be periodised,[10] and specific to the training demands of the sport and individual. Previous research has investigated the use,[38,118-120] and perceived effectiveness,[23,24] of recovery strategies within team sport athletes and medical support staff, with only one study including coaches.[22] However, to date little is known about the recovery practices of swimmers, and how their coaches prescribe recovery

strategies within training and competition. This thesis is the first to capture this information, in which the common findings of Studies One and Two (i.e., Phases One-Three) identified that swimmers and coaches use more recovery strategies in competition than in training. A possible explanation for this discrepancy could be due to the greater number of reported barriers (i.e., lack of time, no access to equipment, lack of motivation) in training, as compared to the competitive environment. Studies One and Two additionally demonstrated the belief effect may influence strategy use, in which recovery strategy use was perceived to be more important during competition, with this reflected in the self-reported and observed usage rates. Given the varying use and perceived effectiveness of strategies by swimmers and coaches across training and competition, targeted education programs must provide information regarding how recovery strategies can be used to enhance athletic outcomes. Particularly, education on the benefits of incorporating recovery strategies into the daily training environment to allow athletes to achieve a higher training quality.

Study Two further explored the use of recovery strategies in swimmers, and extended Study One results, through comparison of self-reported and observed recovery strategy use. To date, there have been no research studies comparing self-reported and observed recovery strategy use in athletes. Observations were included in Study Two as an objective measure of use, due to self-report data being easily influenced by social desirability bias (i.e., systematic bias to the perceived "correct" or socially accepted response).[131] Observational findings revealed swimmers misreport recovery strategy use in both training and competition. This discrepancy highlights the need for a combination of objective and subjective assessment to reduce the effect of social desirability bias when examining the use of recovery strategies in athletes.[131]

The use of semi-structured interviews in Study Two enabled a thorough analysis of swimmer recovery perceptions, where recovery was defined as the ability to return the body to its pre-exercise state. A key finding of this study was that swimmers reported, and were observed to

spontaneously adjust recovery plans on-the-day according to 'feel'. These findings from Study Two may help to explain the discrepancy between coach prescribed and athlete self-reported use of recovery strategies in Study One. Moreover, Study Two was the first study to demonstrate that it is possible athletes have the capacity to self-regulate their recovery on-the-day, with this concept requiring further investigation. The combined results of Studies One and Two highlight the individual nature of recovery strategy use, during both training and competition. Collectively, these results highlight the commonalities in swimmers' recovery strategy perceptions, in which greater importance and effectiveness is placed on recovery interventions during competition. The importance of using a combined approach of subjective and objective methodologies was clear across these two studies to further explain the findings. Further investigation into swimmers' recovery practices is required, to elaborate on the reasons behind strategy use, and investigate athlete's abilities to self-regulate recovery strategies according to 'feel'.

7.1.2 Importance of Recovery and Training Quality in Swimmers

It is possible that increases in training loads that lead to augmented soreness and fatigue over time may reduce training quality,[10] in which recovery strategies could be used to assist the maintenance of training quality. Studies One and Two demonstrated that 'soreness' and 'tiredness or fatigue' were the primary challenges swimmers faced during training, with the 'ability to back up' reported as the greatest challenge within competition. These findings highlight the importance of appropriate recovery, and the application of strategies such as CWI or sleep to maintain training and performance capabilities. This in in agreement with previous findings in which recovery strategies have been shown to improve performance.[11,14] While numerous studies have investigated the acute effects of recovery interventions,[7,10,37,38] less is known about how recovery strategies impact an athlete's ability to train on a day-to-day basis. This may be due to the difficulty to assess training quality, and an absence of a training quality

monitoring tool. Therefore, this thesis aimed to develop a method to quantify training quality in an attempt to better understand how recovery impacts 'training quality' in future research. The concept of training quality was explored using athlete interviews. During the athlete interviews it was identified that the constructs were physical, technical and mental. Moreover, swimmers strongly believed feeling recovered both physically, and mentally were vital to ensuring high training quality within subsequent training sessions. Based on the findings of Studies One and Two, coaches and sport science practitioners should consider the interaction between physical, mental, and emotional recovery status, to enable a flexible approach to recovery programming. This finding is representative of the swimmers' recovery interview responses identified in Study Two, in which swimmers stated they complete recovery to return the body to its pre-exercise state. Additionally, swimmers reported recovering both physically and mentally, to ensure they could adequately perform (i.e., technical quality) across subsequent training sessions. Studies Two and Three establish an association between the aspects that underpin training quality (physical, technical, mental), and the swimmers' justification for use of recovery strategies. The collective results of Studies One, two and Three therefore demonstrate the need for further investigation into the potential relationship between recovery strategies and training quality in swimmers. This concept is represented in the following swimmer's response.

"[recovery is] getting yourself ready to be able to perform in training day after day, and that can mean physically, mentally, even just winding down…"–S1

These findings highlight that athletes and coaches perceive recovery as an important factor to ensure training quality. Appropriate inclusion of recovery strategies within athlete training plans, could promote the maintenance of training quality and performance outcomes.[10] However, this relationship is yet to be examined, and requires further investigation.

7.1.3 Evidence-based practice and a mixed model approach in Sport Science

This thesis is the first to attempt to define the construct of training quality, and develop a subjective assessment tool that can be used in the daily training environment. Training quality is a construct anecdotally used in the assessment of training effectiveness, and commonly discussed between athletes and coaches. The construct of training quality must first be described, before its relationship with recovery, and specific recovery strategies, can be examined. Use of an evidence-based research approach (i.e., understanding key stakeholder opinions),[34] was pertinent for assessing swimmer's training quality perceptions (Study Three). Historically, load monitoring tools have been used to determine an athletes training intensity or duration, with numerous other contributing factors to training overlooked. Therefore, monitoring an athlete's training quality could enhance coaches and sport scientist's understanding of the demands of the training session, an athlete's perceived training ability, and subsequently improve training prescription. Assessment of training quality could therefore promote a holistic approach to athlete monitoring.

A combination of quantitative and qualitative techniques were further used to develop, a subjective tool to assess training quality. A survey of 252 athlete revealed the STQ had a high face validity. Internal consistency and CFA results additionally demonstrated the STQ scale was representative of the construct of training quality. To further validate the STQ scale, comparison with objective training and performance measures was required. To date, it is difficult to quantify swimming performance in the field. The intended purpose of Study Four was to validate a head-worn inertial sensor (TritonWear®) during the competitive swimmers' training to compare with the STQ ratings. However, the wearable device was found to be inaccurate in the independent validation of various swimming metrics. As such, further research and innovation is required to accurately quantify swimming performance metrics in the daily training environment. Specifically, longitudinal studies assessing the validity of the

wearable device across multiple training cycles is required. The STQ ratings were not directly compared with the video swimming metrics, due to video analysis not being typically used within the daily training environment given its limited capacity to provide real-time feedback. Therefore, further studies are required to validate the STQ ratings with objective training quality measures. Through application of the evidence-based best practice model, we have provided initial findings regarding the definition of training quality, and proposed a subjective tool (STQ scale) which could be used to monitor training quality. Further research is required into the training quality concept and STQ scale to adhere to these evidence-based best practice guidelines. Nonetheless, it is proposed that the combined use of a subjective assessment tool (such as the STQ), with objective measures of performance could allow greater insight to an athlete's training response, therefore improving the prescription of training and recovery sessions. The use of a mixed method research design allows application of the evidence-based best practice principles, and enables sport scientists to respond holistically to the questions raised by athletes and coaches within the field. The collective findings of this thesis promote the need for future research into the relationship between recovery and training quality, to determine if recovery strategies can be used to maintain or improve quality. It is likely that improvements in an athlete's recovery status will lead to enhancements in training quality outcomes. Given the novelty of training quality, further exploration of the definition of training quality, and validation of the STQ scale are required.

7.1.4 Summary of Key Findings

The collective results of the present thesis demonstrate recovery strategies are regularly used and prescribed by swimmers and coaches, within training and competition. Swimmers and coaches perceived recovery strategies to be more effective and important during competition, however this was not necessarily reflected in the swimmers' observed strategy use. Indeed, the athlete observations revealed swimmers would exaggerate the frequency of strategy use within

training and competition. Therefore, comparison between subjective and objective measures of recovery are essential. The semi-structured interviews used during Studies Two and Three provided greater insight to swimmer's perceptions of recovery strategies and training quality. Analysis of swimmer interview responses enabled the differentiation of the three primary constructs which underpin training quality. These themes were additionally evident within the swimmer's descriptions of recovery strategy importance. Development of the STQ scale was possible following identification of the training quality constructs. The strong internal consistency, CFA, and face validity responses demonstrate the potential for use of the STQ scale. Further validation of the STQ scale is required, specifically in relation to objective training quality markers in swimmers given the inaccuracy of the wearable device assessed in Study Four. The various findings and further research questions originating from this thesis are represented in a visual flow chart in Figure 7.1.

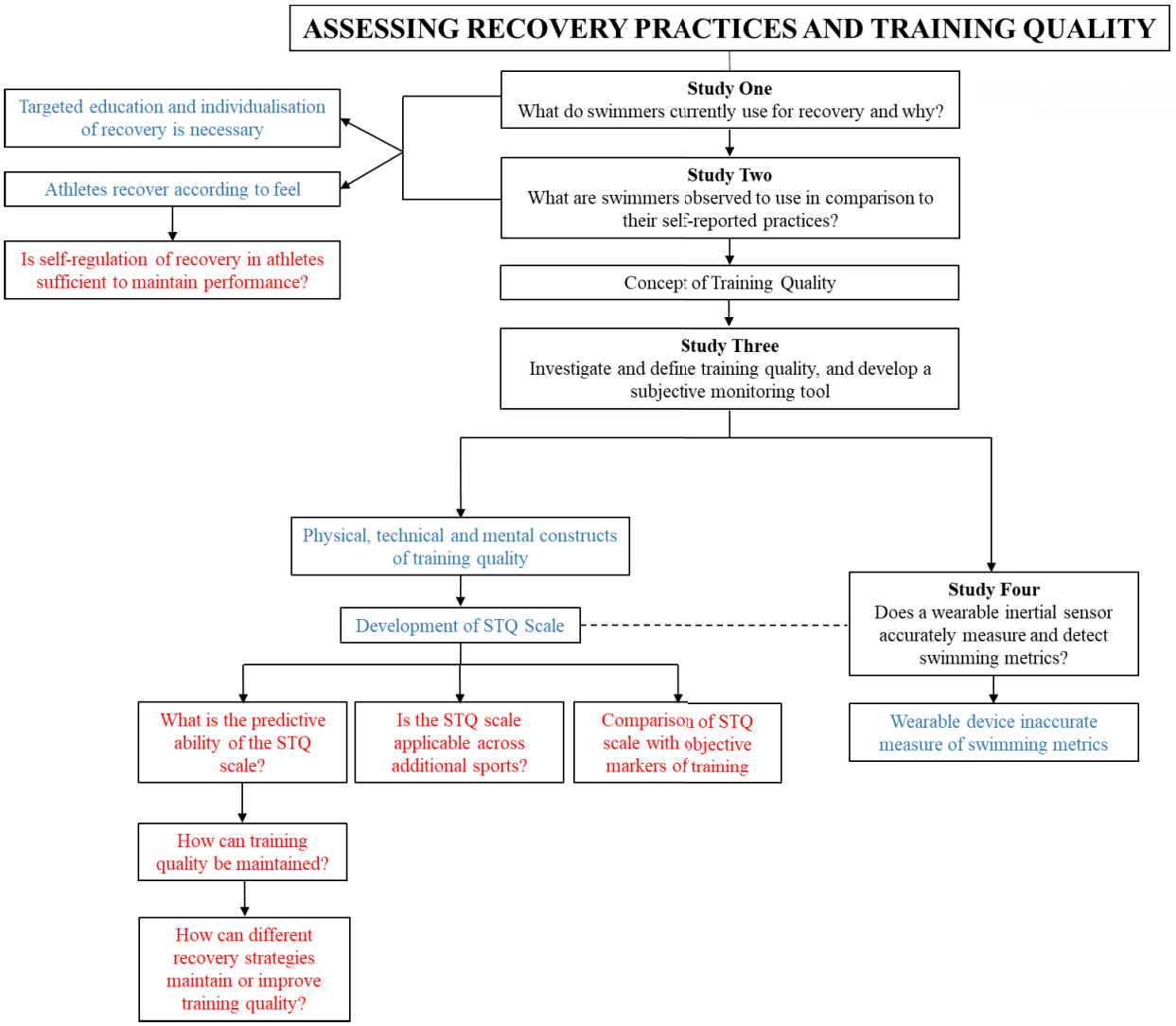

Figure 7.1 Visual flow chart on thesis conception and progression. Text highlighted in blue represents outcomes from thesis studies, and text highlighted in red represents remaining questions. STQ – subjective training quality scale.

7.2 PRACTICAL APPLICATIONS

The findings of this thesis have identified practical recommendations to understand recovery strategy use and perceptions in athletes, and to assess training quality. Figure 7.2 represents a conceptual model for application of the thesis findings, to program recovery strategies and deliver training quality to athletes.

- Where feasible, sport science practitioners should investigate an athlete's current use and perceptions of recovery strategies, using techniques such as surveys, semi-structured interviews and observation. This will assist to tailor education, or proactively design the environment to meet the athlete's needs, therefore increasing the likelihood of adherence. Through understanding current use and perceptions, sport scientists can work to remove potential barriers for athletes and coaches by; providing access to equipment or resources not otherwise available, assisting with integration and practical application of strategies, and developing individualised training and competition recovery plans informed by current evidence-based practice guidelines.

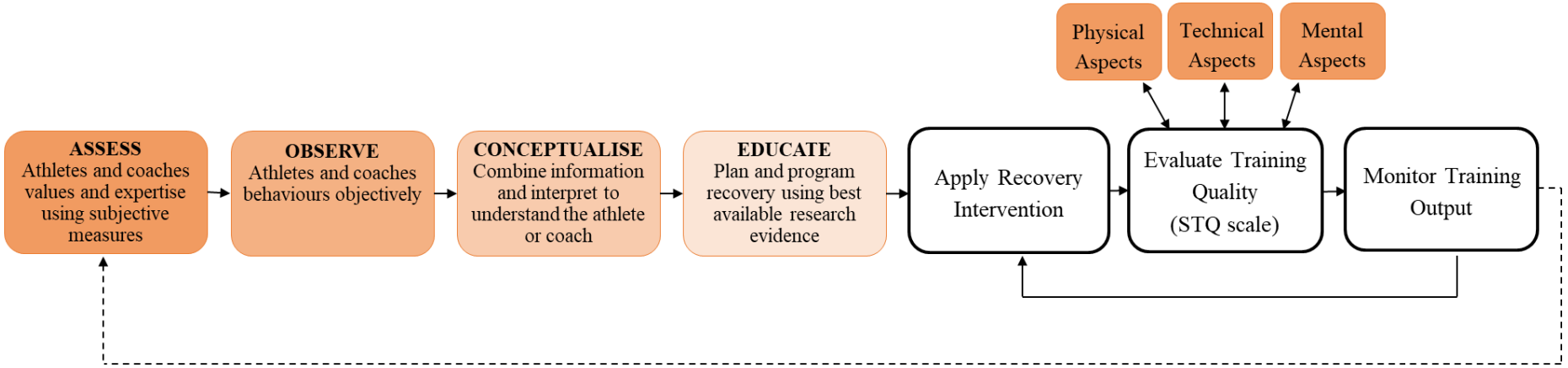

Figure 7.2 Conceptual model for the application and delivery of recovery strategies and training quality to athletes.

- Targeted education programs for athletes and coaches are required to promote appropriate use of recovery strategies in training and competition. Given the influence of the belief effect, appropriate reinforcement of the importance of specific recovery interventions could promote strategy application and effectiveness. Separate education sessions for athletes and coaches will increase specificity to advance strategy knowledge. Delivery should include a combination of workshops, personal interactions, and the promotion of social networks.
- A combined approach of observation and self-reported strategy use can minimise the effect of social desirability bias, and observational limitations. Such a combination may improve recovery strategy individualisation and reporting processes to both athletes and coaches.
- To ensure an athlete's perceived recovery status is considered, the use of a flexible and dynamic approach to recovery strategy prescription may be important. Moreover, incorporating self-regulation skills for recovery during training and competition could enhance athlete recovery. Coaches and sport scientists should consider using self-regulation skills to enhance the recovery process.
- As a result of the excellent face validity, internal consistency, and CFA findings of the STQ scale, it is suggested the scale could be used to monitor training quality. However, further validation of the scale is required prior to implementation.
- Swimmers, coaches, and sport science practitioners require precise data to determine the individual responses to training load. With the current inaccuracy of the monitoring device examined in Study Four it is not recommended for use as a performance or load monitoring tool.

7.3 LIMITATIONS OF THESIS

The studies conducted in this thesis used a combined approach of quantitative and qualitative research methodologies. Consequently, several limitations were identified and are discussed below.

Due to the subjective nature of the recovery survey (Study One) and semi-structured interviews (Study Two), the swimmers' responses were susceptible to the influence of social desirability bias. However, the recovery survey was anonymous, and completed by the swimmers in their own time, without the presence or influence of a coach or scientist. Study Two was additionally limited through a lack of questioning of recovery strategies completed '*At Home*'. Therefore, the recovery strategies used by swimmers in their home or hotel venues in training and competition were not recorded due to observational constraints. As a result, it is possible the discrepancies between self-reported and observed recovery strategy use can be attributed to a lack of questioning following pool departure. These findings are also reflective of the recovery practices within the sample population (i.e., sub-elite and elite Australian swimmers and coaches), and could be reported differently across differing sports and locations. Therefore, it is necessary to use a combination of self-report and observation data to specifically probe swimmers on their strategy use external to the pool. This thesis was additionally limited by a lack of objective assessment of recovery strategy effectiveness during training and competition. Studies One and Two assessed swimmers' perceptions and practices of recovery strategies, however this was not directly related to whether training or performance was improved.

Training quality was defined using a swimming population (Study Three). Therefore, the definition of quality is limited to one, individual-based sport. It is possible other athletes, such as those in team sports, would define training quality differently, or place greater emphasis on varying constructs of quality. Moreover, the instructions before completion of the STQ scale

(Study Three), could create confusion with future research in which athletes can meet their prescribed training objectives, yet will demonstrate poor training quality. Lastly, the mental and emotional engagement should be separated in future iterations of the STQ scale given the differences in mental (e.g., motivation) and emotional constructs (i.e., psychophysiological reactions to the environment).[150]

A limitation of Study Four was the inability to complete a lap-by-lap comparison between the video and device, due to the wearable device lacking a lap timestamp. Given the device was unable to detect a variety of strokes accurately, across a series of training sessions consisting of various drills and efforts, its use as a performance metric monitoring device is limited. Therefore, it is inappropriate to use this device as an objective measure for comparison with the STQ scale ratings, and it remains unknown whether the STQ subsequently reflects the training session. Additionally, due to the inaccuracy of the device, objective comparison with the STQ scale was not possible. This was a limiting factor to the validation of the STQ scale, and overall progression of this thesis.

The primary purpose of this thesis was to investigate swimmers' recovery practices, and understand their perceptions of training quality to subsequently develop a training quality monitoring tool. As such, the relationship between recovery and training quality was not directly examined. Instead, various techniques (i.e., surveys, semi-structured interviews, observation) that can be used to determine athlete's recovery strategy perceptions and practices were identified across three studies. Given the training quality concept has not been previously described, this thesis additionally used evidence-based techniques (i.e., explore and understand athlete values) to described the constructs that underpin training quality, and subsequently develop a training quality monitoring tool. Understanding how and why athletes use recovery strategies, and how training quality can be described and assessed, are important considerations in the process of determining the relationship between recovery and training quality. This thesis

therefore provides a platform for future research into the interaction between recovery interventions, training quality and training outcomes.

7.4 APPLIED IMPACT OF THESIS

Various applied outcomes were evident during implementation and following study completion for of Studies One, Two and Three.

7.4.1 Study One

The recovery survey was initially distributed to a junior swim team prior to a training camp in preparation for the Junior World Championships in Indianapolis, Indiana. Results were disseminated to a number of key stakeholders (e.g., Physiologists, High Performance Manager, Head Coach), and presented as individual, and overall, recovery reports. Following the competition, the Head Coach and director acknowledged the benefits this survey had for their preparation. Specifically, the survey assisted logistical (e.g., equipment to pack) and performance (e.g., improved recovery practices) preparations. This beneficial feedback demonstrates the scope a survey can have on practice within the sporting context.

7.4.2 Study Two

Athlete recovery strategy observations during training and the 2018 Gold Coast, Commonwealth Games swimming trials resulted in various practical applications. During competition, multiple squads identified their Gold medal potential athletes to be monitored during this project. Following observation, reports (i.e., individual and an overall summary) were distributed to various key stakeholders (e.g., Sport Science Director, Physiologists, Head Coach). These stakeholders provided positive feedback following completion of observations. Examples of this feedback include development and individualisation of recovery plans (i.e., athletes were provided detailed advice and a recovery plan according to their individual demands), increased availability of equipment (e.g., the correct equipment was made available

at future events), and squad specific targeted education (e.g., recovery education specific to the squad's needs, such as use of CWI or active recovery). During the Commonwealth Games trials, the swimming organisation High Performance Director reported this study was "the most influential sport science work to be completed" for their athletes. This statement alone highlights the impact of the athlete observations.

7.4.3 Study Three

The subjective training quality scale was administered to a range of sports. Positive feedback was provided from a number of sporting organisations, two of which include an individual-based and team-based sport. Following confirmation of the internal consistency and face validity of the scale, both organisations continue to use the STQ scale. Swimming physiologists closely followed the development and validation of the scale, reporting that the scale has merit in the daily training environment to improve understanding of athlete training quality. One of the rugby teams specifically reported the scale to be "highly useful" in understanding their players' responses to training. During 2019, the scale was also introduced to a wheelchair basketball team. Although assessment of this data is ongoing, coaching and medical staff were very excited and eager to use this scale to better understand their athlete's perception of training quality. This is particularly important for wheelchair basketball, as the program is decentralised and operates Nation-wide. This feedback demonstrates the applicability and merit of using a subjective measurement tool within the applied setting. Further validation of the STQ scale could enable routine use in the daily training environment.

7.5 FUTURE RESEARCH RECOMMENDATIONS

The findings of the present series of studies highlight several considerations for future research to expand upon recovery practices and training quality. Specifically:

- Future research studies are required to further investigate the relationship between recovery and training quality. It is likely that improvements in recovery strategy use will lead to enhanced training quality. However, the construct of training quality and the validity of the STQ scale must firstly be further examined.
- Further investigation into the use of recovery strategies by swimmers is warranted, specifically using a combination of self-report (i.e., survey, semi-structured interviews) and observational methodologies to increase data accuracy. Future observational studies to assess recovery strategy use should combine this with an at-home recovery survey or diary to reduce the likelihood of strategies being overlooked.
- Self-regulation of recovery strategy selection could enhance an athlete's recovery status by recovering according to 'feel'. If athletes have previously demonstrated exercise improvements with self-regulation, it is possible the self-regulation of recovery strategies could enhance recovery status, and subsequently training or competitive performance. It would be important to determine self-regulation capabilities across a broad range of athlete competitive levels, and familiarity with recovery strategies to understand if experience further enables self-regulation.
- Further investigation into the varying constructs of training quality as defined by different sports is required. Future research studies to define training quality should implement various qualitative research methodologies, such as those used within this thesis, to explore and understand the athletes and coaches knowledge and opinions. By investigating training quality across various athletes, the definition of quality will likely be refined and advanced, therefore increasing applicability across a broad range of sports.
- The STQ scale demonstrated excellent internal consistency and face validity, however this was only assessed across eight sports. Therefore, future research should investigate

the use of the STQ in other sports not addressed in Study Three (e.g., athletics). Further validity and reliability assessment of the STQ scale is required. Future research studies should additionally determine how the STQ scale can be used by coaches in conjunction with athlete responses. This will highlight discrepancies between athletes and coaches, helping to improve athlete-coach interactions. The predictive ability of the STQ scale must be explored to understand whether consistently high training quality sessions that meet the prescribed training loads are related to superior performances. Similarly, the relationship between training quality and recovery must be further examined, in which increased training loads demand greater emphasis on adequate inclusion of recovery strategies. Fluctuations in training quality, such as through increased fatigue or decreased motivation, could be indicative of future changes in performance. Additionally, longitudinal research studies are needed to determine the reliability of the STQ over time, and in relation to various objective training or performance outcome measures.

7.6 CONCLUSION

The aim of this thesis was to explore swimmers' recovery strategy practices, and the construct of training quality as defined by competitive swimmers, to subsequently develop a training quality monitoring tool. The sequential explanatory, mixed methods design used for the current thesis resulted in valuable and complete information, and therefore allowed deeper exploration and clarity regarding recovery strategies and training quality in swimmers. The series of four studies presented within this thesis have provided understanding of competitive swimmers, and their coach's recovery strategy perceptions and practices (Study One), and have identified the differences in self-report recovery strategy use, as compared to observed use (Study Two). By understanding how swimmers are currently using recovery strategies, and the reasons for use,

it is possible to tailor education, individualise recovery plans, and increase the likelihood of strategy implementation. Moreover, this thesis provides novel research regarding the concept of training quality. The studies in this thesis are the first to define the constructs that underpin training quality, and develop a training quality monitoring tool (Study Three). This concept of training quality, including physical, technical, and mental constructs, could be used to complement traditional training monitoring tools, therefore providing greater insight into athlete training, and improving training prescription. This thesis additionally initially intended to compare objective training quality markers with the STQ ratings. However, the inaccuracy of the wearable device meant comparison was unable to be completed (Study Four). The outcomes of this thesis contribute to our knowledge of recovery strategy use, and has provided novel findings comparing training and competition strategy use, in addition to self-reported and observed use. Results of this dissertation has additionally attempted, for the first time, to define the concept of training quality, and propose a subjective assessment tool to monitor training quality.

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APPENDIX 1: ATHLETE RECOVERY SURVEY (STUDY ONE)

Authors Note: Athlete recovery survey used in Study One is provided from pages 126 to 159.

Recovery Strategies in Training and Competition Athletes

Recovery Strategies Utilised by Athletes

The questionnaire involves four main sections including demographic information, active recovery practices, passive recovery practices and a summary. The questionnaire should take no more than 25 minutes to complete.

Please note: The questionnaire must not be discussed with other athletes or coaches.

All completed questionnaires are greatly appreciated, and the research team thanks you for your time and effort.

Demographics

Q1 Age

_____

Q2 Gender

- ○ Male
- ○ Female

Q3 What state/territory are you from?

- ○ QLD
- ○ VIC
- ○ NSW
- ○ ACT
- ○ SA
- ○ WA
- ○ TAS
- ○ NT

Q4 What is/are your main event/s?

_____

Q5 How many years have you been participating and competing in your sport?

_____

Q6 What division are you currently competing in (select all which are relevant)?

- ☐ Junior
- ☐ Development
- ☐ State
- ☐ National
- ☐ International
- ☐ None of the above

Q7 Where do you get your recovery information from (select all which are relevant)?

- ☐ Scientific journals
- ☐ Scientific staff
- ☐ Websites/online
- ☐ Coach
- ☐ Other athletes
- ☐ Other (please specify) _____

Active Recovery

Q1 During training and competition the active recovery strategies I use are (select all which are relevant):

	Training	Competition
Warm down (i.e. swim down)	☐	☐
Stretching	☐	☐
Other (please specify)	☐	☐

Q2 How **important** is the warm down for you during training and competition?

	1 Not important	2	3	4	5 Very important
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q3 How **effective** is the warm down for you during training and competition?

	1 Not effective	**2**	**3**	**4**	**5 Very effective**
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q4 How **often** do you complete a warm down after training and competition?

	1 Never	**2**	**3**	**4**	**5 Always**
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q5 Thinking of your most recent competition, the duration of your warm down was:

- ○ Time-based (e.g. for 15 minutes)
- ○ Distance-based (e.g. for 3 km)
- ○ Blood lactate based (e.g. to 2 mmol.L)
- ○ Heart rate based (e.g. to 100 bpm)
- ○ Other (please specify) _____
- ○ None of the above

Q6 Please outline your typical warm down (e.g. swim for 15 minutes, or swim down for 5 km) in training and competition.

- ○ **Training** _____
- ○ **Competition** _____

Q7 Does this differ between races in the same session? If yes, how?

- ○ Yes _____
- ○ No

Q8 Is a warm down more important during training or competition?

- ○ During training
- ○ During competition
- ○ Both

Q9 During competition, is a warm down more important between events or at the end of a competition day?

- ○ Between events
- ○ At the end of a competition day
- ○ Both

Q10 What are your barriers to completing a **warm down** during training and competition (select all which are relevant)?

	Training	Competition
Don't have enough time	☐	☐
No access to equipment and resources	☐	☐
Lack motivation/can't be bothered	☐	☐
Don’t see a benefit/don’t find it effective	☐	☐
Don’t know what to do or when	☐	☐
Too far to travel to access facilities	☐	☐
Other (please specify)	☐	☐
None of the above	☐	☐

Q11 I complete a warm down because it: Please read the list and rate how important you believe each of these reasons is for you.

	1 Strongly disagree	2	3	4	5 Strongly agree
Will increase subsequent performance	○	○	○	○	○
Is what I have seen other elite athletes do	○	○	○	○	○
Is something my coach told me to do	○	○	○	○	○
Helps me to wind down and relax	○	○	○	○	○
Reduces muscle soreness	○	○	○	○	○
Increases blood flow and circulation	○	○	○	○	○
Don’t know	○	○	○	○	○
Other (please specify)	○	○	○	○	○

Stretching

Q1 How **important** is stretching for you during training and competition?

	1 Not important	**2**	**3**	**4**	**5 Very important**
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q2 How **effective** is stretching for you during training and competition?

	1 Not effective	**2**	**3**	**4**	**5 Very effective**
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q3 How **often** do you stretch after training and competition?

	1 Never	**2**	**3**	**4**	**5 Always**
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q4 In total, how long do you stretch for (e.g. 20 minutes) in training and competition?

- ○ **Training** _____
- ○ **Competition** _____

Q5 Is stretching more important during training or competition?

- ○ During training
- ○ During competition
- ○ Both

Q6 During competition, is stretching more important between events or at the end of a competition day?

- ○ Between events
- ○ At the end of a competition day
- ○ Both

Q7 What are your barriers to completing **stretching** during training and competition (select all which are relevant)?

	Training	Competition
Don't have enough time	☐	☐
No access to equipment and resources	☐	☐
Lack motivation/can't be bothered	☐	☐
Don’t see a benefit/don’t find it effective	☐	☐
Don’t know what to do or when	☐	☐
Other (please specify)	☐	☐
None of the above	☐	☐

Q8 I complete stretching because it: Please read the list and rate how important you believe each of these reasons is for you.

	1 Strongly disagree	2	3	4	5 Strongly agree
Will increase subsequent performance	○	○	○	○	○
Is what I have seen other elite athletes do	○	○	○	○	○
Is something my coach told me to do	○	○	○	○	○
Helps me to wind down and relax	○	○	○	○	○
Reduces muscle soreness	○	○	○	○	○
Increases blood flow and circulation	○	○	○	○	○
Don’t know	○	○	○	○	○
Other (please specify)	○	○	○	○	○

Passive Recovery Strategies

Q1 During training and competition the **passive** recovery strategies I use are (select all which are relevant):

	Training	Competition
Nutrition and hydration	☐	☐
Sleep/nap	☐	☐
Progressive muscle relaxation or imagery	☐	☐
Soft tissue therapy (physiotherapy or massage)	☐	☐
Self-massage (i.e. foam rolling)	☐	☐
Reflexology or acupuncture	☐	☐
Compression garments (i.e. tights and tops)	☐	☐
Cold water immersion (ice bath)	☐	☐
Hot water immersion (spa)	☐	☐
Contrast water therapy (alternating hot and cold)	☐	☐
Cold showers	☐	☐
Hot showers	☐	☐
Contrast showers (alternating hot and cold)	☐	☐
Other (please specify)	☐	☐

Sleep

Q1 How **important** is your sleep during training and competition?

	1 Not important	**2**	**3**	**4**	**5 Very important**
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q2 How **effective** is your sleep during training and competition?

	1 Not effective	**2**	**3**	**4**	**5 Very effective**
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q3 How **often** do you nap after training and competition?

	1 Never	**2**	**3**	**4**	**5 Always**
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q4 How **important** are naps for you during training and competition?

	1 Not important	**2**	**3**	**4**	**5 Very important**
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q5 How **effective** are naps for you during training and competition?

	1 Not effective	**2**	**3**	**4**	**5 Very effective**
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q6 On average, how many hours of sleep would you get during training and competition?

○ **Training** _____

○ **Competition** _____

Q7 On average, how long do you nap for during training and competition (e.g. 60 minutes)?

○ **Training** _____

○ **Competition** _____

Q8 Do you have concerns with the quantity or quality of your sleep during training or competition?

	Yes - Quantity	Yes - Quality	Yes to both	No to both	Unsure
Training	○	○	○	○	○
Competition	○	○	○	○	○

Massage

Q1 How **important** is massage for you during training and competition?

	1 Not important	2	3	4	5 Very important
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q2 How **effective** is massage for you during training and competition?

	1 Not effective	2	3	4	5 Very effective
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q3 How **often** do you use massage after training and competition?

	1 Never	**2**	**3**	**4**	**5 Always**
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q4 How long do you receive a massage for in training and competition (e.g. 15 minutes)?

○ **Training** _____

○ **Competition** _____

Q5 Is massage more important during training or competition?

○ During training

○ During competition

○ Both

Q6 During competition, is massage more important between events or at the end of a competition day?

○ Between events

○ At the end of a competition day

○ Both

Q7 What are your barriers to receiving a **massage** during training and competition (select all which are relevant)?

	Training	Competition
Don't have enough time	☐	☐
No access	☐	☐
Lack motivation/can't be bothered	☐	☐
Don’t see a benefit/don’t find it effective	☐	☐
Don’t know what to do or when	☐	☐
Too far to access a massage	☐	☐
Other (please specify)	☐	☐
None of the above	☐	☐

Q8 I receive massage because it: Please read the list and rate how important you believe each of these reasons is for you.

	1 Strongly disagree	2	3	4	5 Strongly agree
Will increase subsequent performance	○	○	○	○	○
Is what I have seen other elite athletes do	○	○	○	○	○
Is something my coach told me to do	○	○	○	○	○
Helps me to wind down and relax	○	○	○	○	○
Reduces muscle soreness	○	○	○	○	○
Increases blood flow and circulation	○	○	○	○	○
Don’t know	○	○	○	○	○
Other (please specify)	○	○	○	○	○

Compression

Q1 How **important** is wearing compression garments for you during training and competition?

	1 Not important	**2**	**3**	**4**	**5 Very important**
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q2 How **effective** are compression garments for you during training and competition?

	1 Not effective	**2**	**3**	**4**	**5 Very effective**
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q3 How **often** do you wear compression garments after training and competition?

	1 Never	**2**	**3**	**4**	**5 Always**
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q4 How long do you wear compression garments for following a training session or a race (minutes or hours)?

- ○ **Training** _____
- ○ **Competition** _____

Q5 Do you sleep in your compression garments following training or competition?

	1 Never	**2**	**3**	**4**	**5 Always**
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q6 Is wearing compression more important following training or competition?

- ○ Following training
- ○ Following competition
- ○ Both

Q7 During competition, is wearing compression more important between events or at the end of a competition day?

- ○ Between events
- ○ At the end of a competition day
- ○ Both

Q8 What are your barriers to wearing **compression garments** during training and competition (select all which are relevant)?

	Training	Competition
Don't have enough time	☐	☐
Don't own any	☐	☐
Lack motivation/can't be bothered	☐	☐
Don’t see a benefit/don’t find it effective	☐	☐
Don’t know what to do or when	☐	☐
Other (please specify)	☐	☐
None of the above	☐	☐

Q9 I wear compression garments because: Please read the list and rate how important you believe each of these reasons is for you.

	1 Strongly disagree	**2**	**3**	**4**	**5 Strongly agree**
They will increase subsequent performance	○	○	○	○	○
It is what I have seen other elite athletes do	○	○	○	○	○
It is something my coach told me to do	○	○	○	○	○
They help me to wind down and relax	○	○	○	○	○
They reduce muscle soreness	○	○	○	○	○
They increase blood flow and circulation	○	○	○	○	○
Don’t know	○	○	○	○	○
Other (please specify)	○	○	○	○	○

Cold Water Immersion (Ice Bath)

Q1 How **important** is using cold water immersion (ice bath) for you during training and competition?

	1 Not important	**2**	**3**	**4**	**5 Very important**
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q2 How **effective** is cold water immersion (ice bath) for you during training and competition?

	1 Not effective	**2**	**3**	**4**	**5 Very effective**
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q3 How **often** do you use cold water immersion (ice bath) after training and competition?

	1 Never	**2**	**3**	**4**	**5 Always**
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q4 On average, how long do you perform cold water immersion (ice bath) for during training and competition (e.g. 10 minutes)?

- **Training** _____
- **Competition** _____

Q5 Is cold water immersion (ice bath) more important during training or competition?

- During training
- During competition
- Both

Q6 During competition, is cold water immersion (ice bath) more important between events or at the end of a competition day?

- Between events
- At the end of a competition day
- Both

Q7 What are your barriers to completing **cold water immersion (ice bath)** during training and competition (select all which are relevant)?

	Training	Competition
Don't have enough time	☐	☐
No access to equipment and resources	☐	☐
Lack motivation/can't be bothered	☐	☐
Too cold	☐	☐
Not cold enough	☐	☐
Don’t see a benefit/don’t find it effective	☐	☐
Don’t know what to do or when	☐	☐
Too far to travel to access facilities	☐	☐
Other (please specify)	☐	☐
None of the above	☐	☐

Q8 I complete cold water immersion (ice bath) because it: Please read the list and rate how important you believe each of these reasons is for you.

	1 Strongly disagree	2	3	4	5 Strongly agree
Will increase subsequent performance	○	○	○	○	○
Is what I have seen other elite athletes do	○	○	○	○	○
Is something my coach told me to do	○	○	○	○	○
Helps me to wind down and relax	○	○	○	○	○
Reduces muscle soreness	○	○	○	○	○
Increases blood flow and circulation	○	○	○	○	○
Don’t know	○	○	○	○	○
Other (please specify)	○	○	○	○	○

Contrast Water Therapy

Q1 How **important** is using contrast water therapy (alternating hot and cold) for you during training and competition?

	1 Not important	**2**	**3**	**4**	**5 Very important**
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q2 How **effective** is contrast water therapy (alternating hot and cold) for you during training and competition?

	1 Not effective	**2**	**3**	**4**	**5 Very effective**
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q3 How **often** do you use contrast water therapy (alternating hot and cold) after training and competition?

	1 Never	**2**	**3**	**4**	**5 Always**
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q4 On average, how long do you spend completing contrast water therapy (alternating hot and cold) during training and competition (e.g. 5 minutes hot, 5 minutes cold)?

- ○ **Training** _____
- ○ **Competition** _____

Q5 Do you spend longer in the hot or cold?

- ○ Hot
- ○ Cold
- ○ Equal parts
- ○ Unsure

Q6 Is contrast water therapy (alternating hot and cold) more important during training or competition?

- ○ During training
- ○ During competition
- ○ Both

Q7 During competition, is contrast water therapy (alternating hot and cold) more important between events or at the end of a competition day?

- ○ Between events
- ○ At the end of a competition day
- ○ Both

Q8 What are your barriers to completing **contrast water therapy (alternating hot and cold)** during training and competition (select all which are relevant)?

	Training	Competition
Don't have enough time	☐	☐
No access to equipment and resources	☐	☐
Lack motivation/can't be bothered	☐	☐
Don’t see a benefit/don’t find it effective	☐	☐
Don’t know what to do or when	☐	☐
Too far to travel to access facilities	☐	☐
Other (please specify)	☐	☐
None of the above	☐	☐

Q9 I complete contrast water therapy (alternating hot and cold) because it: Please read the list and rate how important you believe each of these reasons is for you.

	1 Strongly disagree	2	3	4	5 Strongly agree
Will increase subsequent performance	○	○	○	○	○
Is what I have seen other elite athletes do	○	○	○	○	○
Is something my coach told me to do	○	○	○	○	○
Helps me to wind down and relax	○	○	○	○	○
Reduces muscle soreness	○	○	○	○	○
Increases blood flow and circulation	○	○	○	○	○
Don’t know	○	○	○	○	○
Other (please specify)	○	○	○	○	○

Summary

Q1 How much of an issue are the following for your recovery during training and competition? Please read the list and rate how important you believe each of these reasons is for you according to the scale below:
1 = Strongly disagree, 2, 3, 4, 5 = Strongly agree

	Training	**Competition**
Soreness		
Tiredness/fatigue		
Getting enough sleep		
Managing injury		
Managing illness		
Ability to back up		
Stress/anxiety		
Other (please specify)		

Q2 Out of all of the recovery strategies, which have you found the **most** effective (please select only one)?

- ○ Sleep/nap
- ○ Warm down (i.e. swim down)
- ○ Stretching
- ○ Progressive muscle relaxation or imagery
- ○ Soft tissue therapy (physiotherapy or massage)
- ○ Self-massage (i.e. foam rolling)
- ○ Reflexology or acupuncture
- ○ Compression garments (i.e. tights and tops)
- ○ Cold water immersion (ice bath)
- ○ Hot water immersion (spa)
- ○ Contrast water therapy (alternating hot and cold)
- ○ Cold showers
- ○ Hot showers
- ○ Contrast showers (alternating hot and cold)
- ○ Other (please specify) _____

Q3 Any additional comments?

_____

APPENDIX 2: COACH RECOVERY SURVEY (STUDY ONE)

Authors Note: Coach recovery survey used in Study One is provided from pages 161 to 196.

Recovery Strategies in Training and Competition Coaches

Recovery Strategies Utilised by Athletes

The questionnaire involves four main sections including demographic information, active recovery practices, passive recovery practices and a summary. The questionnaire should take no more than 25 minutes to complete

Please note: The questionnaire must not be discussed with other athletes or coaches.

All completed questionnaires are greatly appreciated, and the research team thanks you for your time and effort.

Demographics

Q1 Age

_____

Q2 Gender

- ○ Male
- ○ Female

Q3 What state/territory are you from?

- ○ QLD
- ○ VIC
- ○ NSW
- ○ ACT
- ○ SA
- ○ WA
- ○ TAS
- ○ NT

Q4 What is your current coaching qualification level?

- ○ Elite
- ○ Level 3
- ○ Level 2
- ○ Level 1
- ○ Overseas
- ○ No qualification
- ○ Unknown
- ○ Other (please specify) _____

Q5 How many years have you been coaching?

_____

Q6 How many athletes do you coach?

_____

Q7 How old are the athletes you coach?

_____

Q8 What division are your athletes (select all which are relevant)?

- [ ] Junior
- [ ] Development
- [ ] State
- [ ] National
- [ ] Internation
- [ ] None of the above

Q9 What is/are your athlete's main event/s?

_____

Q10 Where do you get your recovery information from (select all which are relevant)?

- [ ] Scientific journals
- [ ] Scientific staff
- [ ] Websites/online
- [ ] Other coaches
- [ ] Conferences/workshops
- [ ] Other (please specify) _____

Active Recovery

Q1 During training and competition the **active** recovery strategies my athletes use are (select all which are relevant):

	Training	Competition
Warm down (i.e. swim down)	☐	☐
Stretching	☐	☐
Other (please specify)	☐	☐

Q2 How **important** is the warm down during training and competition?

	1 Not important	2	3	4	5 Very important
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q3 How **effective** is the warm down during training and competition?

	1 Not effective	2	3	4	5 Very effective
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q4 How **often** do your athletes complete a warm down after training and competition?

	1 Never	**2**	**3**	**4**	**5 Always**
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q5 Thinking of the most recent competition, the duration of your athletes warm down was:

- ○ Time-based (e.g. for 15 minutes)
- ○ Distance-based (e.g. for 3 km)
- ○ Blood lactate based (e.g. to 2 mmol.L)
- ○ Heart rate based (e.g. to 100 bpm)
- ○ Other (please specify) _____
- ○ None of the above

Q6 Please outline your athlete's typical warm down (e.g. swim for 15 minutes, or swim down for 5 km) in training and competition.

- ○ **Training** _____
- ○ **Competition** _____

Q7 Does this differ between races in the same session? If yes, how?

- ○ Yes _____
- ○ No

Q8 Is a warm down more important during training or competition?

- ○ During training
- ○ During competition
- ○ Both

Q9 During competition, is a warm down more important between events or at the end of a competition day?

- ○ Between events
- ○ At the end of a competition day
- ○ Both

Q10 What are your athlete's barriers to completing a **warm down** during training and competition (select all which are relevant)?

	Training	Competition
Don't have enough time	☐	☐
No access to equipment and resources	☐	☐
Lack motivation/can't be bothered	☐	☐
Don’t see a benefit/don’t find it effective	☐	☐
Don’t know what to do or when	☐	☐
Too far to travel to access facilities	☐	☐
Other (please specify)	☐	☐
None of the above	☐	☐

Q11 My athletes complete a warm down because it: Please read the list and rate how important you believe each of these reasons is for you.

	1 Strongly disagree	2	3	4	5 Strongly agree
Will increase subsequent performance	○	○	○	○	○
Is something I have told them to do	○	○	○	○	○
Helps them to wind down and relax	○	○	○	○	○
Reduces muscle soreness	○	○	○	○	○
Increases blood flow and circulation	○	○	○	○	○
Don’t know	○	○	○	○	○
Other (please specify)	○	○	○	○	○

Stretching

Q1 How **important** is stretching during training and competition?

	1 Not important	2	3	4	5 Very important
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q2 How **effective** is stretching during training and competition?

	1 Not effective	2	3	4	5 Very effective
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q3 How **often** do your athletes stretch after training and competition?

	1 Never	2	3	4	5 Always
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q4 In total, how long do your athletes stretch for (e.g. 20 minutes) in training and competition?

- ○ **Training** _____
- ○ **Competition** _____

Q5 Is stretching more important during training or competition?

- ○ During training
- ○ During competition
- ○ Both

Q6 During competition, is stretching more important between events or at the end of a competition day?

- ○ Between events
- ○ At the end of a competition day
- ○ Both

Q7 What are your athlete's barriers to completing **stretching** during training and competition (select all which are relevant)?

	Training	Competition
Don't have enough time	☐	☐
No access to equipment and resources	☐	☐
Lack motivation/can't be bothered	☐	☐
Don’t see a benefit/don’t find it effective	☐	☐
Don’t know what to do or when	☐	☐
Other (please specify)	☐	☐
None of the above	☐	☐

Q8 My athletes complete stretching because it: Please read the list and rate how important you believe each of these reasons is for you.

	1 Strongly disagree	2	3	4	5 Strongly agree
Will increase subsequent performance	○	○	○	○	○
Is something I have told them to do	○	○	○	○	○
Helps them to wind down and relax	○	○	○	○	○
Reduces muscle soreness	○	○	○	○	○
Increases blood flow and circulation	○	○	○	○	○
Don’t know	○	○	○	○	○
Other (please specify)	○	○	○	○	○

Passive Recovery Strategies

Q1 During training and competition the **passive** recovery strategies my athletes use are (select all which are relevant):

	Training	Competition
Nutrition and hydration	☐	☐
Sleep/nap	☐	☐
Progressive muscle relaxation or imagery	☐	☐
Soft tissue therapy (physiotherapy or massage)	☐	☐
Self-massage (i.e. foam rolling)	☐	☐
Reflexology or acupuncture	☐	☐
Compression garments (i.e. tights and tops)	☐	☐
Cold water immersion (ice bath)	☐	☐
Hot water immersion (spa)	☐	☐
Contrast water therapy (alternating hot and cold)	☐	☐
Cold showers	☐	☐
Hot showers	☐	☐
Contrast showers (alternating hot and cold)	☐	☐
Other (please specify)	☐	☐

Sleep

Q1 How **important** is sleep during training and competition?

	1 Not important	**2**	**3**	**4**	**5 Very important**
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q2 How **effective** is sleep during training and competition?

	1 Not effective	**2**	**3**	**4**	**5 Very effective**
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q3 How **often** do your athletes nap after training and competition?

	1 Never	**2**	**3**	**4**	**5 Always**
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q4 How **important** are naps during training and competition?

	1 Not important	**2**	**3**	**4**	**5 Very important**
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q5 How **effective** are naps during training and competition?

	1 Not effective	**2**	**3**	**4**	**5 Very effective**
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q6 On average, how many hours of sleep would your athletes get during training and competition?

○ **Training** _____

○ **Competition** _____

Q7 On average, how long do your athletes nap for during training and competition (e.g. 60 minutes)?

- ○ **Training** _____
- ○ **Competition** _____

Q8 Do you have concerns with the quantity or quality of your athletes sleep during training or competition?

	Yes - Quantity	Yes - Quality	Yes to both	No to both	Unsure
Training	○	○	○	○	○
Competition	○	○	○	○	○

Massage

Q1 How **important** is massage during training and competition?

	1 Not important	**2**	**3**	**4**	**5 Very important**
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q2 How **effective** is massage during training and competition?

	1 Not effective	**2**	**3**	**4**	**5 Very effective**
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q3 How **often** do your athletes use massage after training and competition?

	1 Never	**2**	**3**	**4**	**5 Always**
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q4 How long do your athletes receive a massage for in training and competition (e.g. 15 minutes)?

- ○ **Training** _____
- ○ **Competition** _____

Q5 Is massage more important during training or competition?

- ○ During training
- ○ During competition
- ○ Both

Q6 During competition, is massage more important between events or at the end of a competition day?

- ○ Between events
- ○ At the end of a competition day
- ○ Both

Q7 What are your athlete's barriers to receiving a **massage** during training and competition (select all which are relevant)?

	Training	Competition
Don't have enough time	☐	☐
No access	☐	☐
Lack motivation/can't be bothered	☐	☐
Don’t see a benefit/don’t find it effective	☐	☐
Don’t know what to do or when	☐	☐
Too far to access a massage	☐	☐
Other (please specify)	☐	☐
None of the above	☐	☐

Q8 My athletes receive massage because it: Please read the list and rate how important you believe each of these reasons is for you.

	1 Strongly disagree	2	3	4	5 Strongly agree
Will increase subsequent performance	○	○	○	○	○
Is something I have told them to do	○	○	○	○	○
Helps them to wind down and relax	○	○	○	○	○
Reduces muscle soreness	○	○	○	○	○
Increases blood flow and circulation	○	○	○	○	○
Don’t know	○	○	○	○	○
Other (please specify)	○	○	○	○	○

Compression

Q1 How **important** is wearing compression garments during training and competition?

	1 Not important	**2**	**3**	**4**	**5 Very important**
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q2 How **effective** are compression garments during training and competition?

	1 Not effective	**2**	**3**	**4**	**5 Very effective**
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q3 How **often** do your athletes wear compression garments after training and competition?

	1 Never	**2**	**3**	**4**	**5 Always**
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q4 How long do your athletes wear compression garments for following a training session or a race (minutes or hours)?

- ○ **Training** _____
- ○ **Competition** _____

Q5 Do your athletes sleep in their compression garments following training or competition?

	1 Never	**2**	**3**	**4**	**5 Always**
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q6 Is wearing compression more important following training or competition?

- ○ Following training
- ○ Following competition
- ○ Both

Q7 During competition, is wearing compression more important between events or at the end of a competition day?

- ○ Between events
- ○ At the end of a competition day
- ○ Both

Q8 What are your athletes barriers to wearing **compression garments** during training and competition (select all which are relevant)?

	Training	Competition
Don't have enough time	☐	☐
Don't own any	☐	☐
Lack motivation/can't be bothered	☐	☐
Don’t see a benefit/don’t find it effective	☐	☐
Don’t know what to do or when	☐	☐
Other (please specify)	☐	☐
None of the above	☐	☐

Q9 My athletes wear compression garments because: Please read the list and rate how important you believe each of these reasons is for you.

	1 Strongly disagree	2	3	4	5 Strongly agree
They will increase subsequent performance	○	○	○	○	○
It is something I have told them to use	○	○	○	○	○
They help them to wind down and relax	○	○	○	○	○
They reduce muscle soreness	○	○	○	○	○
They increase blood flow and circulation	○	○	○	○	○
Don’t know	○	○	○	○	○
Other (please specify)	○	○	○	○	○

Cold Water Immersion (ice bath)

Q1 How **important** is using cold water immersion (ice bath) during training and competition?

	1 Not important	**2**	**3**	**4**	**5 Very important**
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q2 How **effective** is cold water immersion (ice bath) during training and competition?

	1 Not effective	**2**	**3**	**4**	**5 Very effective**
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q3 How **often** do your athletes use cold water immersion (ice bath) after training and competition?

	1 Never	**2**	**3**	**4**	**5 Always**
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q4 On average, how long do your athletes perform cold water immersion (ice bath) for during training and competition (e.g. 10 minutes)?

- ○ **Training** _____
- ○ **Competition** _____

Q5 Is cold water immersion (ice bath) more important during training or competition?

- ○ During training
- ○ During competition
- ○ Both

Q6 During competition, is cold water immersion (ice bath) more important between events or at the end of a competition day?

- ○ Between events
- ○ At the end of a competition day
- ○ Both

Q7 What are your athletes barriers to completing **cold water immersion (ice bath)** during training and competition (select all which are relevant)?

	Training	Competition
Don't have enough time	☐	☐
No access to equipment and resources	☐	☐
Lack motivation/can't be bothered	☐	☐
Too cold	☐	☐
Not cold enough	☐	☐
Don’t see a benefit/don’t find it effective	☐	☐
Don’t know what to do or when	☐	☐
Too far to travel to access facilities	☐	☐
Other (please specify)	☐	☐
None of the above	☐	☐

Q8 My athletes complete cold water immersion (ice bath) because it: Please read the list and rate how important you believe each of these reasons is for you.

	1 Strongly disagree	2	3	4	5 Strongly agree
Will increase subsequent performance	○	○	○	○	○
Is what I have told them to do	○	○	○	○	○
Helps them to wind down and relax	○	○	○	○	○
Reduces muscle soreness	○	○	○	○	○
Increases blood flow and circulation	○	○	○	○	○
Don’t know	○	○	○	○	○
Other (please specify)	○	○	○	○	○

Contrast Water Therapy

Q1 How **important** is using contrast water therapy (alternating hot and cold) during training and competition?

	1 Not important	2	3	4	5 Very important
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q2 How **effective** is contrast water therapy (alternating hot and cold) during training and competition?

	1 Not effective	2	3	4	5 Very effective
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q3 How **often** do your athletes use contrast water therapy (alternating hot and cold) after training and competition?

	1 Never	**2**	**3**	**4**	**5 Always**
Training	○	○	○	○	○
Competition	○	○	○	○	○

Q4 On average, how long do your athletes spend completing contrast water therapy (alternating hot and cold) during training and competition (e.g. 5 minutes hot, 5 minutes cold)?

- ○ **Training** _____
- ○ **Competition** _____

Q5 Do your athletes spend longer in the hot or cold?

- ○ Hot
- ○ Cold
- ○ Equal parts
- ○ Unsure

Q6 Is contrast water therapy (alternating hot and cold) more important during training or competition?

- ○ During training
- ○ During competition
- ○ Both

Q7 During competition, is contrast water therapy (alternating hot and cold) more important between events or at the end of a competition day?

- ○ Between events
- ○ At the end of a competition day
- ○ Both

Q8 What are your athlete's barriers to completing **contrast water therapy (alternating hot and cold)** during training and competition (select all which are relevant)?

	Training	Competition
Don't have enough time	☐	☐
No access to equipment and resources	☐	☐
Lack motivation/can't be bothered	☐	☐
Don’t see a benefit/don’t find it effective	☐	☐
Don’t know what to do or when	☐	☐
Too far to travel to access facilities	☐	☐
Other (please specify)	☐	☐
None of the above	☐	☐

Q9 My athletes complete contrast water therapy (alternating hot and cold) because it: Please read the list and rate how important you believe each of these reasons is for you.

	1 Strongly disagree	2	3	4	5 Strongly agree
Will increase subsequent performance	○	○	○	○	○
Is something I have told them to do	○	○	○	○	○
Helps them to wind down and relax	○	○	○	○	○
Reduces muscle soreness	○	○	○	○	○
Increases blood flow and circulation	○	○	○	○	○
Don’t know	○	○	○	○	○
Other (please specify)	○	○	○	○	○

Summary

Q1 How much of an issue are the following for your athlete's recovery during training and competition?
Please read the list and rate how important you believe each of these reasons is for your athletes according to the scale below:
1 = Strongly disagree, 2, 3, 4, 5 = Strongly agree

	Training	**Competition**
Soreness		
Tiredness/fatigue		
Getting enough sleep		
Managing injury		
Managing illness		
Ability to back up		
Stress/anxiety		
Other (please specify)		

Q2 Out of all of the recovery strategies, which have you found the **most** effective (please select only one)?

- ○ Sleep/nap
- ○ Warm down (i.e. swim down)
- ○ Stretching
- ○ Progressive muscle relaxation or imagery
- ○ Soft tissue therapy (physiotherapy or massage)
- ○ Self-massage (i.e. foam rolling)
- ○ Reflexology or acupuncture
- ○ Compression garments (i.e. tights and tops)
- ○ Cold water immersion (ice bath)
- ○ Hot water immersion (spa)
- ○ Contrast water therapy (alternating hot and cold)
- ○ Cold showers
- ○ Hot showers
- ○ Contrast showers (alternating hot and cold)
- ○ Other (please specify) _____

Q3 Any additional comments?

_____

APPENDIX 3: HUMAN RESEARCH ETHICS COMMITTEE APPROVAL LETTERS

Authors Note: Universty of Technology Sydney Human Ethics approval letters for Studies One to Four are provided from pages 198 to 207.

HREC Approval Granted - ETH17-1228

Research.Ethics@uts.edu.au

Fri 07/04/2017 17:41

To: Aaron Coutts <Aaron.Coutts@uts.edu.au>; Steph Shell <Stephanie.J.Shell@student.uts.edu.au>; Research Ethics <research.ethics@uts.edu.au>

Dear Applicant

Thank you for your response to the Committee's comments for your project titled, "Recovery Strategies Utilised by Athletes and Coaches". Your response satisfactorily addresses the concerns and questions raised by the Committee who agreed that the application now meets the requirements of the NHMRC National Statement on Ethical Conduct in Human Research (2007). I am pleased to inform you that ethics approval is now granted.

Your approval number is UTS HREC REF NO. ETH17-1228.

Approval will be for a period of five (5) years from the date of this correspondence subject to the provision of annual reports.

Your approval number must be included in all participant material and advertisements. Any advertisements on the UTS Staff Connect without an approval number will be removed.

Please note that the ethical conduct of research is an on-going process. The National Statement on Ethical Conduct in Research Involving Humans requires us to obtain a report about the progress of the research, and in particular about any changes to the research which may have ethical implications. This report form must be completed at least annually from the date of approval, and at the end of the project (if it takes more than a year). The Ethics Secretariat will contact you when it is time to complete your first report.

I also refer you to the AVCC guidelines relating to the storage of data, which require that data be kept for a minimum of 5 years after publication of research. However, in NSW, longer retention requirements are required for research on human subjects with potential long-term effects, research with long-term environmental effects, or research considered of national or international significance, importance, or controversy. If the data from this research project falls into one of these categories, contact University Records for advice on long-term retention.

You should consider this your official letter of approval. If you require a hardcopy please contact Research.Ethics@uts.edu.au.

To access this application, please follow the URLs below:
* if accessing within the UTS network: https://rm.uts.edu.au
* if accessing outside of UTS network: https://vpn.uts.edu.au , and click on " RM6 – Production " after logging in.

We value your feedback on the online ethics process. If you would like to provide feedback please go to: http://surveys.uts.edu.au/surveys/onlineethics/index.cfm

If you have any queries about your ethics approval, or require any amendments to your research in the future, please do not hesitate to contact Research.Ethics@uts.edu.au.

Yours sincerely,

Associate Professor Beata Bajorek
Chairperson
UTS Human Research Ethics Committee
C/- Research & Innovation Office
University of Technology, Sydney
E: Research.Ethics@uts.edu.au

HREC Approval Granted - ETH17-1537

Research.Ethics@uts.edu.au

Fri 16/06/2017 17:05

To: Steph Shell <Stephanie.J.Shell@student.uts.edu.au>; Aaron Coutts <Aaron.Coutts@uts.edu.au>; Research Ethics <research.ethics@uts.edu.au>

Dear Applicant

UTS HREC REF NO. ETH17-1537

The UTS Human Research Ethics Expedited Review Committee reviewed your amendment application for your project titled, "Recovery Strategies Utilised by Athletes and Coaches", and agreed that the amendments meet the requirements of the NHMRC National Statement on Ethical Conduct In Human Research (2007). I am pleased to inform you that the Committee has approved your request to amend the protocol as follows:
Swimming Australia have requested the names of athletes and coaches to be identified. As such, we are seeking approval for the questionnaire data to be identifiable. This amendment would require the addition of the participants name (for athletes and coaches) and home coach name (for athletes) to the questionnaires.

You should consider this your official letter of approval. If you require a hardcopy please contact the Research Ethics Officer (Research.Ethics@uts.edu.au).

To access this application, please follow the URLs below:
* if accessing within the UTS network: https://rm.uts.edu.au
* if accessing outside of UTS network: https://vpn.uts.edu.au , and click on " RM6 – Production " after logging in.

We value your feedback on the online ethics process. If you would like to provide feedback please go to: http://surveys.uts.edu.au/surveys/onlineethics/index.cfm

If you wish to make any further changes to your research, please contact the Research Ethics Officer in the Research and Innovation Office, Ms Valeria Passo on 02 9514 2478.

In the meantime I take this opportunity to wish you well with the remainder of your research.

Yours sincerely,

Associate Professor Beata Bajorek
Chairperson
UTS Human Research Ethics Committee
C/- Research & Innovation Office
University of Technology, Sydney
E: Research.Ethics@uts.edu.au

HREC Approval Granted - ETH17-1677

Research.Ethics@uts.edu.au

Fri 06/10/2017 11:12

To: Aaron Coutts <Aaron.Coutts@uts.edu.au>; Steph Shell <Stephanie.J.Shell@student.uts.edu.au>; Research Ethics <research.ethics@uts.edu.au>

Dear Applicant

Thank you for your response to the Committee's comments for your project titled, "Athlete's and coaches' perceptions of recovery practices during training and competition.". Your response satisfactorily addresses the concerns and questions raised by the Committee who agreed that the application now meets the requirements of the NHMRC National Statement on Ethical Conduct in Human Research (2007). I am pleased to inform you that ethics approval is now granted.

Your approval number is UTS HREC REF NO. ETH17-1677.
Approval will be for a period of five (5) years from the date of this correspondence subject to the provision of annual reports.

Your approval number must be included in all participant material and advertisements. Any advertisements on the UTS Staff Connect without an approval number will be removed.

Please note that the ethical conduct of research is an on-going process. The National Statement on Ethical Conduct in Research Involving Humans requires us to obtain a report about the progress of the research, and in particular about any changes to the research which may have ethical implications. This report form must be completed at least annually from the date of approval, and at the end of the project (if it takes more than a year). The Ethics Secretariat will contact you when it is time to complete your first report.

I also refer you to the AVCC guidelines relating to the storage of data, which require that data be kept for a minimum of 5 years after publication of research. However, in NSW, longer retention requirements are required for research on human subjects with potential long-term effects, research with long-term environmental effects, or research considered of national or international significance, importance, or controversy. If the data from this research project falls into one of these categories, contact University Records for advice on long-term retention.

You should consider this your official letter of approval. If you require a hardcopy please contact Research.Ethics@uts.edu.au.

To access this application, please follow the URLs below:
* if accessing within the UTS network: https://rm.uts.edu.au
* if accessing outside of UTS network: https://remote.uts.edu.au , and click on "RM6 - ResearchMaster Enterprise" after logging in.

We value your feedback on the online ethics process. If you would like to provide feedback please go to: http://surveys.uts.edu.au/surveys/onlineethics/index.cfm

If you have any queries about your ethics approval, or require any amendments to your research in the future, please do not hesitate to contact Research.Ethics@uts.edu.au.

Yours sincerely,

Associate Professor Beata Bajorek
Chairperson
UTS Human Research Ethics Committee
C/- Research & Innovation Office
University of Technology, Sydney
E: Research.Ethics@uts.edu.au

REF: E38

HREC Approval Granted - ETH17-1599

Research.Ethics@uts.edu.au

Mon 21/08/2017 19:05

To: Aaron Coutts <Aaron.Coutts@uts.edu.au>; Steph Shell <Stephanie.J.Shell@student.uts.edu.au>; Research Ethics <research.ethics@uts.edu.au>

Dear Applicant

Thank you for your response to the Committee's comments for your project titled, "Recovery strategy use during training and competition: an observational study". Your response satisfactorily addresses the concerns and questions raised by the Committee who agreed that the application now meets the requirements of the NHMRC National Statement on Ethical Conduct in Human Research (2007). I am pleased to inform you that ethics approval is now granted on the condition that evidence of SERAP approval is provided to the Ethics Secretariat when obtained.

Your approval number is UTS HREC REF NO. ETH17-1599.

Approval will be for a period of five (5) years from the date of this correspondence subject to the provision of annual reports.

Your approval number must be included in all participant material and advertisements. Any advertisements on the UTS Staff Connect without an approval number will be removed.

Please note that the ethical conduct of research is an on-going process. The National Statement on Ethical Conduct in Research Involving Humans requires us to obtain a report about the progress of the research, and in particular about any changes to the research which may have ethical implications. This report form must be completed at least annually from the date of approval, and at the end of the project (if it takes more than a year). The Ethics Secretariat will contact you when it is time to complete your first report.

I also refer you to the AVCC guidelines relating to the storage of data, which require that data be kept for a minimum of 5 years after publication of research. However, in NSW, longer retention requirements are required for research on human subjects with potential long-term effects, research with long-term environmental effects, or research considered of national or international significance, importance, or controversy. If the data from this research project falls into one of these categories, contact University Records for advice on long-term retention.

You should consider this your official letter of approval. If you require a hardcopy please contact Research.Ethics@uts.edu.au.

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We value your feedback on the online ethics process. If you would like to provide feedback please go to: http://surveys.uts.edu.au/surveys/onlineethics/index.cfm

If you have any queries about your ethics approval, or require any amendments to your research in the future, please do not hesitate to contact Research.Ethics@uts.edu.au.

Yours sincerely,

Associate Professor Beata Bajorek
Chairperson
UTS Human Research Ethics Committee
C/- Research & Innovation Office
University of Technology, Sydney
E: Research.Ethics@uts.edu.au

HREC Approval Granted - ETH18-2368

Research.Ethics@uts.edu.au

Thu 03/05/2018 15:45

To: Aaron Coutts <Aaron.Coutts@uts.edu.au>; Steph Shell <Stephanie.J.Shell@student.uts.edu.au>; Research Ethics <research.ethics@uts.edu.au>

Dear Applicant

Thank you for your response to the Committee's comments for your project titled, "Development and Validity of the Training Quality Scale.". Your response satisfactorily addresses the concerns and questions raised by the Committee who agreed that the application now meets the requirements of the NHMRC National Statement on Ethical Conduct in Human Research (2007). I am pleased to inform you that ethics approval is now granted.

Your approval number is UTS HREC REF NO. ETH18-2368.
Approval will be for a period of five (5) years from the date of this correspondence subject to the provision of annual reports.

Your approval number must be included in all participant material and advertisements. Any advertisements on the UTS Staff Connect without an approval number will be removed.

Please note that the ethical conduct of research is an on-going process. The National Statement on Ethical Conduct in Research Involving Humans requires us to obtain a report about the progress of the research, and in particular about any changes to the research which may have ethical implications. This report form must be completed at least annually from the date of approval, and at the end of the project (if it takes more than a year). The Ethics Secretariat will contact you when it is time to complete your first report.

I also refer you to the AVCC guidelines relating to the storage of data, which require that data be kept for a minimum of 5 years after publication of research. However, in NSW, longer retention requirements are required for research on human subjects with potential long-term effects, research with long-term environmental effects, or research considered of national or international significance, importance, or controversy. If the data from this research project falls into one of these categories, contact University Records for advice on long-term retention.

You should consider this your official letter of approval. If you require a hardcopy please contact Research.Ethics@uts.edu.au.

To access this application, please follow the URLs below:
* if accessing within the UTS network: https://rm.uts.edu.au
* if accessing outside of UTS network: https://remote.uts.edu.au , and click on "RM6 - ResearchMaster Enterprise" after logging in.

If you have any queries about your ethics approval, or require any amendments to your research in the future, please do not hesitate to contact Research.Ethics@uts.edu.au.

Yours sincerely,

Associate Professor Beata Bajorek
Chairperson
UTS Human Research Ethics Committee

C/- Research & Innovation Office
University of Technology, Sydney
E: Research.Ethics@uts.edu.au

REF: E38

Your ethics application has been approved as low risk - ETH18-2341

research.ethics@uts.edu.au

Tue 15/05/2018 11:14

To: Steph Shell <Stephanie.J.Shell@student.uts.edu.au>; Aaron Coutts <Aaron.Coutts@uts.edu.au>
Cc: Chris Fernandes <Christopher.Fernandes@uts.edu.au>; Karen Gomez <Karen.Gomez@uts.edu.au>; Priya Nair <Priya.Nair@uts.edu.au>; Rebekah Tatian <Rebekah.Tatian@uts.edu.au>

Dear Applicant

Your local research office has reviewed your application titled, "Validity and reliability of TritonWear as a measure of training load in swimmers.", and agreed that the application meets the requirements of the National Statement on Ethical Conduct in Human Research (2007). I am pleased to inform you that ethics approval has now been granted.

Your approval number is UTS HREC REF NO. ETH18-2341.
You should consider this your official letter of approval. If you require a hardcopy please contact your local research office.

Approval will be for a period of five (5) years from the date of this correspondence subject to the provision of annual ethics reports to your local research office.

Your approval number must be included in all participant material and advertisements. Any advertisements on the UTS Staff Connect without an approval number will be removed.

Please note that the ethical conduct of research is an on-going process. The National Statement on Ethical Conduct in Human Research (2007) requires us to obtain reports about the progress of the research, and in particular about any changes to the research which may have ethical implications. You will be contacted when it is time to complete your first report.

Please refer to the AVCC guidelines relating to the storage of data, which require that data be kept for a minimum of 5 years after publication of research. However, in NSW, longer retention requirements are required for research on human subjects with potential long-term effects, research with long-term environmental effects, or research considered of national or international significance, importance, or controversy. If the data from this research project falls into one of these categories, contact University Records for advice on long-term retention.

To access this application, please follow the URLs below:
* if accessing within the UTS network: https://rm.uts.edu.au
* if accessing outside of UTS network: https://vpn.uts.edu.au , and click on " RM6 – Production " after logging in.

If you have any queries about this approval, or require any amendments to your approval in future, please do not hesitate to contact your local research office or Research.Ethics@uts.edu.au.

REF: 12a

APPENDIX 4: SEMI-STRUCTURED INTERVIEW GUIDE (STUDIES TWO AND THREE)

Authors Note: Semi-structured interview guide used in Studies Two and Three is provided from pages 209 to 210.

Interview Guide – Athletes

Question	Prompts	Purpose
1. Can you tell me a bit about your swimming history?	• What has been your biggest success? • Tell me a little about the swimming you do now	• Establishes rapport • Indicates their highest competitive achievement • What level athlete, sprint/long distance
2. What are your thoughts on completing a swim down a. In training? b. In competition?	• Do you think the swim down helps you to train harder at the next training session? • Do you think the swim down helps you to perform better in your next race? • How/why do you think this? • Do you think swim downs could be completed differently?	• Provides understanding as to their belief in active recovery, and how it could be improved • Insight into the athletes' understanding of how the swim down works
3. Are you aware of passive recovery strategies?	• Do you think these strategies are important to use? • When is it important to use these strategies? a. In training? b. In competition? • What is your usual recovery routine following training and competition? • Why did you select these strategies? • Are these the recovery strategies you rely on the most?	• Gauges understanding of what passive recovery strategies are and how they use them

4. Tell me about how you use recovery during a typical week of training and during competition	• Is recovery prescribed for you, or used as required/self-selected? • Do you periodise your recovery strategies? • How do you decide on your recovery strategies? • Why do you use recovery in this way?	• Provides greater insight to how recovery is used and why recovery practices may differ
5. Is there anything that stops you from completing your recovery routine?	• How does this differ while at training or competition? • Is there another strategy you would like to use but can't? – Why?	• This will provide understanding to what stops athletes from completing recovery – is it due to resources, time or knowledge etc.
6. How much is training and performance impacted by recovery status?	• Do you think you swim slower if you do not complete adequate recovery either between training sessions or races?	• Establishes the importance of recovery
7. Do you think the quality of a training session is important to improving swim performance?	• How do you measure your training quality?	• Establishes the importance of an athlete's training session and provides understanding of training quality measurement tools