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DOCTOR OF PHILOSOPHY

The Role of Athlete Availability in the Development of Young Elite Athletes

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The Role of Athlete Availability in the Development of Young Elite Athletes

A thesis submitted to Bangor University in fulfilment of the requirements

for the Degree of Doctor of Philosophy at the School of Human and Behavioural Sciences,

Bangor University.

Megan V. Lowery

10th March 2022

Declaration

I hereby declare that this thesis is the result of my investigations, except where otherwise stated. All other sources are acknowledged by bibliographic references. This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree unless, as agreed by the University, for approved dual awards.
I confirm that I am submitting this work with the agreement of my Supervisor(s).

Yr wyf drwy hyn yn datgan mai canlyniad fy ymchwil fy hun yw'r thesis hwn, ac eithrio lle nodir yn wahanol. Caiff ffynonellau eraill eu cydnabod gan droednodiadau yn rhoi cyfeiriadau eglur. Nid yw sylwedd y gwaith hwn wedi cael ei dderbyn o'r blaen ar gyfer unrhyw radd, ac nid yw'n cael ei gyflwyno ar yr un pryd mewn ymgeisiaeth am unrhyw radd oni bai ei fod, fel y cytunwyd gan y Brifysgol, am gymwysterau deuol cymeradwy.
Rwy'n cadarnhau fy mod yn cyflwyno'r gwaith hwn gyda chytundeb fy Ngoruchwyliwr (Goruchwylwyr)

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List of abbreviations

ADFS - Athlete Development Formulation Survey

AMQ – Athlete Monitoring Questionnaire

ASSQ -Athlete Sleep Screening Questionnaire

CDFS - Coach Development Formulation Survey

COVID-19 - Coronavirus disease

DE – Developing elite

DMSP - Developmental Model of Sport Participation

GPS - Global Positioning Systems

HoT – Head of Talent

OSTRC – Oslo Sports Trauma Research Centre

P2P – Pathway to Podium

PPS - Prospective Psychosocial Survey

PRS – Perceived Recovery Scale

PSS – Perceived Stress Scale

PSQI – Pittsburgh Sleep Quality Index

NF –Non-funded athletes

RAE – Relative Age Effect

RPE – Rate of Perceived Exertion

T – Time Point

TPR – True Positive Rate

WCP – World Class Programme

WHO – World Health Organisation

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Thesis summary

The present thesis aimed to advance our understanding of athlete availability in the talent development process of developing elite athletes. The thesis contains five chapters, three of which are empirical studies.

Chapter 1 provides a broad review of the literature surrounding athlete availability, athlete monitoring, and the talent development process of developing elite athletes. This review highlights the existing literature surrounding athlete availability in developing elite athletes and underscores the current gaps in the literature. It should be noted that further exploration of the literature is referenced in subsequent chapters. Chapter 1 ends with the aims of the thesis, namely, how does athlete availability and the determinants of athlete availability differ between non-funded (NF) and developing elite athletes? What are the determinants of athlete availability in a developing elite athletic population? How important is athlete availability, sleep, well-being, and health in the context of talent development and progression?

In Chapter 2, over fourteen weeks, I examined differences between NF and developing elite athletes on determinants of availability (training, health, sleep, stress, and wellbeing). Findings revealed that, despite greater training loads, developing elite athletes were more available, and reported better sleep, lower levels of stress, and greater wellbeing than their NF counterparts.

Chapter 3 used pattern recognition analyses to identify the combination of training and health variables that best discriminated between athletes with lower and higher training availability (relating to health and training modification) in a cohort of developing elite swimmers using pattern recognition analyses. Fifteen developing elite swimmers completed the Athlete Monitoring Questionnaire (AMQ) for 63 weeks, via an online platform, reporting their training and competition availability, training volumes, sleep, wellbeing, stress, and health (injury and illness). The findings identified that training availability is not determined through unidimensional constructs; rather availability is best understood via a multidimensional approach, which considers (at least) training, sleep, and wellbeing.

Chapter 4 was written as a scientific report produced for Swim England and British Swimming. This empirical study aimed to identify the combination of training and health (biopsychosocial, training, and health) factors that were important to discriminate between higher potential - high-level athletes who were identified as most likely to progress in the high-performance system – and lower potential athletes – high-level athletes less likely to progress in the high-performance system. Using pattern recognition analyses, I examined data collected from the Swim England Performance Squad over 18 months. These data are related to the athletes' practice and training, psychosocial characteristics, coach-athlete relationships, health (e.g., injury, illness, wellbeing, and sleep), and training metrics (e.g., hours, distance, and perceived effort). The results of the pattern recognition analyses revealed that the main discriminators related to psychosocial factors, coach-athlete communication, wellbeing, sleep, and perceived challenge within training.

Chapter 5 discusses the theoretical and applied implications of the current thesis. A common theme throughout the empirical chapters was that the determinants of athlete availability are best understood via a multidimensional approach. Accordingly, it is vital to measure and consider the interactive effect of a wide variety of bio-psycho-social variables together. Furthermore, athlete availability is important in progressing and thriving in the high-performance system. However, the influence of athlete availability varies at different stages of an athlete's development.

This thesis has begun to advance the theoretical understanding between athlete availability and talent development. The pattern recognition analyses of the empirical Chapters 3 and 4 highlighted that practitioners wanting to improve athlete availability and their ability to thrive in the high-performance system might do so by reducing athlete psychological stress and improving wellbeing, improving athlete education on sleep behaviours, having a greater focus on coach-athlete communication around goal-setting, and supporting coaches to manage their wellbeing and athletes with more challenging personality profiles.

Thesis context

This PhD thesis is part of a larger project known as the Pathway 2 Podium (P2P) project. The P2P project reflects a collaboration between Bangor University and UK Sport. Unlike many talent identification and development projects, P2P was a longitudinal and prospective study of podium potential athletes. The podium potential pathway aims to identify, support, and develop younger athletes who demonstrate the capability of progressing through the high-performance system. The P2P project attempted to identify factors that influence the development of high-level sports performers. Specifically, I examined the complex ways in which different pathway, individual, and coaching factors affected athlete availability and ability to thrive in the high-performance sports environment. The term ‘thrive’ is operationalised by UK Sport in several different ways. These include; athlete availability (i.e., the extent to which an athlete can complete their prescribed training to an optimal standard); athlete progression (e.g., transition up the pathway towards the Podium Programme, competition achievements, adaptability to change, and increased load and expectations placed on the athlete via the Pathway); and attrition (e.g., withdrawal from high-level sport). The factors under investigation included demographics (e.g., birth place, and schooling), early life experience (e.g., relationship with parents/guardians,), practice and training variables (e.g., training volumes, developmental sporting history, milestones, and achievements in sport, past and current training activities), health (e.g., sleep, wellbeing, stress, injury, and illness), psychosocial factors (e.g., personality and behavioural characteristics), coaching (e.g., coach-athlete relationship, coaching style and support provided), and organisational variables (e.g., the culture of the sporting environment). There were three PhD researchers and six academics involved in this project. Each PhD focused on related but distinctly different research topics:

- Miss Megan Lowery ‘The Role of Athlete Availability in the Development of Young Elite Athletes
- Miss Emily Dunn ‘Pathway 2 Podium: Talent Development in Elite Hockey Players’ (Title TBC)
- Dr Eleanor Langham Walsh ‘Pathway 2 Podium: A Multidisciplinary and Mixed Method Approach to Enhancing the Efficacy of Talent Development Systems’, Viva completed 28/07/2021

I refer the reader to the other theses for further and more detailed information on the measures that were not the focus of this PhD. The focus of this PhD is on athlete availability in a developing elite population. Thus, my specific contribution to the P2P project was largely focused on the health and performance of athletes. In the first 18 months of the P2P project, I led the development of athlete monitoring measures and an associated feedback system, details of which are discussed as part of Chapter 2 of this thesis and examples of which can be found in the appendix and supplementary material. Further to this, I worked collaboratively on the development and validation of the psychosocial measures, and I was involved in validating these measures. More details on the psychosocial measures can be found in Langham-Walsh (2021, PhD Thesis) for details on measure development and validation. As mentioned, evidence of the applied work completed as part of this PhD is provided in the appendices.

The use of ‘I’ and ‘we’

As is consistent with convention from APA guidelines, I utilise the pronoun ‘I’ where appropriate. However, I emphasise that this PhD was collaborative and so, where appropriate the pronoun ‘we’ is utilised.

Considerations of PhD formatting

This PhD has been written in line with APA guidelines. The labelling of tables and figures restart each chapter but to make it clear, they are numbered as per the chapter they appear in (e.g., any tables or figures in Chapter 2 commence with a 2).

Chapter 1: General introduction

1.1 The importance of athletic training for the development of sporting talent

The substantial rewards of winning major sporting events have helped drive the past two decades of research in athletic talent development. There is building evidence that points towards the process of developing world-class sporting success as a complex interaction of hereditary prerequisites and environmental factors (Vaeyens et al., 2008; Williams et al., 2020). The importance of relative age effect (Helsen et al., 2005), maturation (Saward et al., 2020), sport specialisation and diversification (Coutinho et al., 2016), and psychological characteristics (Hardy et al., 2017) are just some of the widely researched areas within the talent identification and development literature. It is well accepted that to enhance sporting performance, physical stress (e.g., training loads) and psychological stress (e.g., pressure) should be adjusted to an appropriate duration, frequency, and intensity to elicit the desired training adaptations (Halson, 2014). Whilst insufficient training load results in undertraining and therefore underperformance, excessive physical training and psychological stress coupled with inadequate recovery, can impair athlete performance and lead to ill health (Bourdon et al., 2017). These impairments may arise in the form of injury, illness, overtraining or burnout, which all have the potential to hinder athlete availability i.e., the extent to which an athlete can complete their prescribed training to an optimal standard. An athlete needs to be available to train and compete to accumulate the domain-specific and effortful training hours required for athletic development (Güllich & Emrich, 2014; Rees et al., 2016; Tucker & Collins, 2012). It is therefore reasonable to assert that athlete availability is an important factor in the talent development process. However, to date, there is a lack of research into athlete availability in the context of talent development, and thus the influence of availability on the development of talent is poorly understood.

1.2 What is known about athlete availability?

Substantial injuries and illnesses (health problems), regardless of age or stage of a sporting career, affect an athlete's availability to complete their prescribed training to an optimal standard (Hägglund et al., 2013; Podlog et al., 2015). A study of Norwegian Olympic athletes over five consecutive Olympic Games cycles (2012 – 2020) revealed that athletes lost 27 days of training per year due to health problems (Clarsen et al., 2021). The consequences of health problems and a subsequent lack of athlete availability to participate in training are profound and can negatively affect game, match, or competition performance (Raysmith & Drew, 2016). Ultimately, athlete unavailability may hinder the ability of an athlete or team to progress through their respective performance pathways. While athlete availability has clear and direct implications for training and performance, wider economic and societal issues are also present. Availability, and more specifically the lack of availability, can carry a financial burden. Organisations with unavailable athletes may encounter issues such as relegation, and therefore lose considerable amounts of funding (King et al., 2022; Stewart, 2017). It is estimated that injuries cost a football team in the English Premier League approximately £45 million per season (Eliakim et al., 2020). Alternatively, athletes or teams may fail to qualify for major events, such as the Olympics or World Cups, which offer revenue-building opportunities.

The existing literature examining athlete availability has done so prospectively, to explore the influence of availability across time. However, many of these studies have focused on elite team sports (Hoffman et al., 2020), or adult males (Caparrós et al., 2016) with a distinct lack of literature examining athlete availability in individual sports, within females, and in developing elite athletes. The extant literature is useful in aiding our thinking about availability; however, it would be misleading to draw inferences from elite adult male athletic studies to developing elite athletes. The determinants of athlete availability and athletic progression at these different career time points of the talent development continuum might differ considerably. Thus, examining availability in these underexplored groups is required.

Further, inconsistencies exist in research findings concerning athlete availability and how the impact on performance is measured (e.g., match availability, team ranking position, points, or goals; Lu et al., 2021; Raysmith & Drew, 2016). These existing studies fail to capture the true extent of the health problem burden. By focusing on missed games or training days, the research does not consider that athletes often participate in training or competitions but are unable to participate fully and perform at the required level. These studies fail to measure the impact of more minor health problems that limit but do not wholly prevent, an athlete from training or competing. This limitation is important as many sports medicine leaders contend that elite sporting organisations are more likely to adopt sports health problem prevention strategies if health problems prove to limit athlete performance or add financial burden (Hoffman et al., 2020).

There has been a recent growth in sports injury and illness surveillance and education on the correct implementation of prevention systems in the hope that athletes can avoid such problems (Ekegren et al., 2015; Vriend et al., 2017). The value of education on prevention strategies has been demonstrated in basketball. Emery et al. (2021) demonstrated that an injury prevention education programme reduced knee and ankle injuries by 36% across the season of high school basketball teams. Despite recent growth in research centred on injury and illness, there is comparably less evidence-based information concerning health problem trends in amateur and community sports, female athletes, developing elite athletes and across a wide variety of sports (Ekegren et al., 2015).

Considering these limitations, the prospective study of athlete availability and progression in developing elite athletes is paramount to understand the important determinants of athlete availability more precisely at the development stage of the elite athletic continuum.

1.3 Athlete availability in the talent identification and development process

There is a combination of prerequisites that exist in the pursuit of long-term elite sports training and ultimately, success (Rees et al., 2017). However, having all, one, or some of these genetic, demographic, training-related, psychosocial, or physiological variables is not a guarantee for success. Nor does the absence of one of these in childhood mitigate the chance of success in adulthood (Vaeyens et al., 2008). There is a much more complex interaction of factors, shaped by an individual's maturation, daily beliefs, and experiences, which may determine the outcome of an athlete's sporting journey. Thus, talent development literature is increasingly utilising a multidimensional approach (Dimundo et al., 2021; Tribolet et al., 2018). Despite what may seem an all-encompassing approach adopted by previous studies, the talent development literature has not yet considered the availability of an athlete to train and compete. This could be a result of the assumption that availability is a prerequisite for sporting success however, due to the lack of conclusive evidence, we cannot be certain.

To identify the determinants of an athlete's ability to thrive in the high-performance system, research has attempted to negotiate this complex interaction between various psychological, physiological, demographic, and sociographic variables (Rees et al., 2017). However, there is no multidimensional study investigating the development of elite youth athletes. What is more, very little is known about the relationship between possible determinants of athlete availability and talent development of elite youth athletes.

1.4 What determinants predict athlete (un) availability?

Given the centrality of availability to athletic performance and sports organisation success, applied sports practitioners have increasingly adopted a more scientific approach to understanding what factors may determine injury and illness, and consequently affect athlete availability (Bourdon et al., 2017; Coutts et al., 2019). According to the International Olympic Committee's consensus statement on methods for recording and reporting epidemiological data on injury and illness in sports, a health problem is defined as any condition that causes a reduction in a normal state of full health, irrespective of its consequences on an individual's sports participation or performance, or whether an individual has sought medical attention (Clarsen et al., 2020).

Stern et al. (2020) propose that researchers, medical professionals, and applied sports scientists should consider injury and illness prediction like a hurricane, whereby predicting the pathway of a hurricane is an imperfect science. In much the same way, Bittencourt et al. (2016) proposed that injury and illness prediction involve a similarly complex and dynamic web of determinants. The web of determinants is continually changing and acting upon an individual, thereby moving them along a continuum between the two athletic states, available and unavailable. Some determinants may act as stressors, such as training load, whilst other determinants may act as protective factors, such as sleep. Some of the typical measurements that may increase or decrease injury and illness risk and hence influence athlete availability are discussed below. These include training load, recovery from athletic training, sleep, perceived stress, and general well-being.

1.41Training volume (external load) and perceived effort (internal load)

Training load, or workload, is the stress placed on the body during physical activity. Optimal training causes acute fatigue leading to adaptation of physiological systems and athlete function (Halson, 2014). This adaptation occurs with the provision of adequate recovery, to overcome the resultant fatigue and to protect against overtraining, injury, and illness (Halson, 2014). Training load comprises both internal and external units; external workload quantifies the work completed by an athlete whilst internal workload refers to the athletes' experience of the workload (Halson, 2014). Monitoring both external and internal workload provides insight into the capability and capacity of an athlete to complete a task under different fatigue states (Bourdon et al., 2017; Brink et al., 2012; Murphy et al., 2014). Data can then be utilised to inform practitioners on appropriate training or recovery methods.

Practitioners often quantify external training load through volume. For example, an athlete's total training or competition hours, distances or repetitions completed, games or races accomplished, or watts produced can be used to quantify external workload (Soligard et al., 2016). Global positioning systems (GPS) are commonly used in field-based sports (Coutts & Duffield, 2010) as they are valid and reliable measures of distance, velocity, time in particular zones, accelerations, and decelerations (Varley et al., 2012). Whilst GPS is valuable to invasion sports like football, these data are of less use to artistic sports such as gymnastics, where subjective (perceptual) measures of load may be more appropriate. Further, subjective measures may be better linked to athlete wellbeing, perceived recovery, and the current state of fatigue (Bourdon et al., 2017). Being able to uncouple internal and external loads alongside subjective and objective data is advantageous in determining the fatigue state of an athlete such that athletes may complete the same load on different days (i.e., same distance) but with varying internal loads (e.g., heart rate) depending on their current state of fatigue. Thus, self-report measures of volume via training diaries are an accepted alternative (Patel et al., 2021; Saw et al., 2016) as they allow for increased sensitivity in understanding the acute and chronic training loads experienced by the athlete (Bourdon et al., 2017).

Internal load is an indication of how the body reacts to given volumes. The rating of perceived exertion scale (RPE; Borg., 1998) is one of the more widely used subjective tools, developed to measure an athlete's perception of the physiological requirements of a task. A benefit of using RPE is its flexibility. Measures can be taken during a bout of exercise (e.g., providing a score based on the current exercise) or post-exercise (e.g., providing a score of perceived exertion based on the overall session). Considerable research across athletic and healthy populations (Reed & Pipe, 2016), clinical populations (Haddad et al., 2017), resistance (Naclerio et al., 2015), endurance (Sharma & Mujika, 2017), and team sports (e.g., football; Clarke et al., 2013) has established this measure as a valid indicator of internal load. For example, Impellizzeri et al. (2004) explored the correlation between RPE and different heart rate-based measures and found significant positive correlations between heart rate and RPE at different intensities. This study, like many others (see Haddad et al., 2017 for a review) established RPE as a valid indicator of an internal load of exercise training. However, post-exercise, RPE may have promise in team sport environments or in sports where the coach does not have access to or time for continuous communication with their athlete (e.g., swimming and canoe slalom) or for athletes completing multiple sessions every day. As a result, it is possible to modify the timing of the RPE scale whereby an overall RPE for a training week is provided (Phibbs et al., 2017). Whilst an overall RPE does not provide a true reflection of individual sessions, this weekly measure still indicates the overall weekly effort whilst being less burdensome than regular reporting and analysis of every training session.

1.42 Recovery from athletic training

The balance between training load and recovery determines the ability of an athlete to adapt and achieve continuous high-level performance, whilst avoiding injury and illness (Kellmann et al., 2018). Given the centrality of recovery to athlete availability and thus, sports organisation success, research has established many psychological and physiological markers to monitor athlete recovery. Hormonal, biochemical, and immunological markers such as creatine kinase (an objective marker of muscle damage) are utilised in team sports such as rugby (McLellan, Lovell, & Gass, 2011). Alternatively, subjective markers such as the REST-Q for athletes (RESTQ-Sport; Kellman & Kallus, 2001), have received mounting interest within sport (Jones et al., 2016). Whilst cheaper and easier to implement compared to hormonal markers, the REST-Q is long. It contains 76 items clustered into 19 subscales, thus is time-consuming (and in some cases unrealistic) for respondents to complete. In addition, it is not freely available, so incurs a financial cost, which may make it impractical for some. Alternatively, the Perceived Recovery Status (PRS; Laurent et al., 2011) scale is a time-effective and validated alternative (Paul et al., 2019). Based upon the RPE scale, the PRS is a single-item scale that asks individuals to subjectively rate their perceived level of recovery where zero reflects feelings of being very poorly recovered and 10 reflects feelings of being very well recovered. Whilst the REST-Q is considered the gold-standard measure of perceived recovery across sporting populations (Jones et al., 2016), the PRS is a preferable alternative when the end-user focus is paramount.

1.43 Sleep

Sleep is one of the most valuable recovery strategies for athletic performance (Juliff et al., 2015, O’Donnell et al., 2018). Evidence suggests athletes who obtain less than the recommended 7-8 hours of sleep (Chaput et al., 2020) may suffer from problems with their physiological performance, well-being, cognitive functioning, motivation, and health (Fox et al., 2020). Despite its physiological and psychological benefits, sleep is often neglected by athletes (Halson, 2014). Leeder et al. (2012) found that when comparing the sleep characteristics of a cohort of Olympic athletes in comparison to a non-athletic healthy control group, the athletic group demonstrated poorer sleep quantity and quality than their non-athletic counterparts. Assessment of both quantity and quality is essential in understanding an athlete’s sleep as both have implications for health (Pilcher, 1997). Meta-analyses have revealed that disrupted sleep, both in quantity and quality, is associated with the increased onset of Type 2 diabetes (Anothaisintawee et al., 2016; Cappuccio et al., 2010). Further, sleep quality and quantity are associated with feeling alert, motivated, and refreshed (Hull et al., 2003), all of which may influence an athletes ability to train optimally (Knufinke et al., 2017).

Given the importance of sleep to health, several measures to assess sleep quantity and quality are available. Polysomnography, the gold standard measure of sleep, involves the measurement of brain function, eye movement and muscle activity through scalp and skin surface electrode recordings (O'Donnell et al., 2018). This method involves considerable experimental control, cost, and equipment. Actigraphy - the process of monitoring movements using a wristwatch device – is a more practical solution considering its non-invasive and portable technology (O'Donnell et al., 2018). However, both polysomnography and actigraphy are impractical for many individuals and clubs given the time burden of collecting and interpreting daily data. Further, wearable devices utilise objective data around the movement to ascertain the quality of sleep (i.e., low movement, high-quality sleep; Aili et al., 2017). However, this so-called objective measure fails to consider an individual's perception of their sleep, which is just as important (Bin, 2016; Kohyama, 2021).

The Pittsburgh Sleep Quality Index (PSQI; Buysse et al., 1989) is a widely used questionnaire completed monthly that provides data on perceptions of sleep quality. It is the most widely used subjective measure of sleep (Buysse et al., 1989) as it demonstrates strong validity and reliability across clinical and non-clinical populations (Mollayeva et al., 2016) and athletes (Knufinke et al., 2018). However, this scale has been criticised for lacking sensitivity to the unique challenges faced by athletes (e.g., travel demands, impaired sleep onset due to competitive pressures and late-night training, and the scheduling of early training sessions; Biggins et al., 2019; Samuels et al., 2016; Walsh et al., 2020). Considering these criticisms, a subjective, self-report, sleep-screening questionnaire for pathway athletes known as the Athlete Sleep Screening Questionnaire (ASSQ; Samuels et al., 2016) was developed. The ASSQ is valid as a tool for sleep screening in collegiate athletes (Rabin et al., 2020), senior, and developing athletes (Bender et al., 2018). The ASSQ builds upon the PSQI by considering athlete-specific factors such as travel. Nevertheless, the PSQI remains the gold standard self-report measure of sleep quality (Landry, Best, & Liu-Ambrose, 2015) not least because it is quick and easy to administer and score.

1.44 Perceived Stress

From non-funded to elite sports, athletes routinely expose themselves to large amounts of physical and psychological stress in the pursuit of their sporting goals. These stress demands allow an athlete to gain maximal adaption. However, an inadequately recovered athlete or an athlete who perceives the stress to be greater than what they can cope with may be at risk of deleterious health outcomes. For example, research has established a clear link between psychological stress and suppressed immune and hormonal function, increased risk of cardiovascular disease, depression, lowered wellbeing, increased vulnerability to injury and illness, disturbed sleep, and increased mortality rate (Dhabhar, 2014; Halson, 2014; Pensgaard et al., 2018). With the implications for health and performance in mind, monitoring individual stress is necessary to achieve balance between training and performance adaptation (Hamlin et al., 2019).

Physical measures of stress include biochemical, cardiovascular and performance indicators (Bourdon et al., 2017; Saw et al., 2016) yet these are often confounded by psychological stress. Overtraining syndrome (OTS) is one such example whereby alterations in psychological symptoms of OTS such as poor mood (Meeusen et al., 2013). Psychological measures can be more sensitive to an athletes' stress response compared to physiological measures (Saw et al., 2016). The most used scale to measure stress is the Perceived Stress Scale (PSS; Cohen et al., 1983). The PSS measures an individual's appraisal of daily life situations and the degree to which they perceive them as stressful. The validity of the 14, 10, and 4-item variant scales has been well established (Lee, 2012; Roberti et al., 2006; Taylor, 2015; Vallejo et al., 2018) making the PSS a good measure of perceived stress.

1.45 Wellbeing

Wellbeing is not merely the absence of disease or infirmity but should encompass all aspects of health whereby an individual’s basic needs, such as adequate physical health, food, education, safety, and socialisation are met, alongside the feelings of life satisfaction, positive emotions and whether their life has meaning (Tay & Diener, 2011). Disturbances in self-reported wellbeing in athletes are associated with overtraining (Bourdon et al., 2017; Saw et al., 2016), injury (Galambos et al., 2005; Ivarsson et al., 2017; Johnson & Ivarsson, 2017; Pensgaard et al., 2018), and illness (Brink et al., 2012; Nieman et al., 1990; Schwellnus et al., 2016). Therefore, wellbeing may also be useful in tracking and predicting an athlete’s availability to train and compete. The wellbeing and mental health of athletes has been a focus of recent publications with exploration of how to best monitor athlete mental health (Lebrun & Collins, 2017; Reardon et al., 2019; Schwellnus et al., 2016; Soligard et al., 2016). One example proposed as a good indicator of wellbeing is the Short-Form 36 (SF-36) Health Survey (Ware & Sherbourne, 1992). Whilst shown to be valid and reliable in clinical populations (LoMartire et al., 2020), it is not appropriate for regular completion given the number of questions (36 items). In contrast, the 5-item World Health Organisation (WHO-5) wellbeing scale is a widely used measure assessing subjective psychological wellbeing. This questionnaire has good content validity in both younger (Blom et al., 2012) and elderly populations (Lucas-Carrasco et al., 2012) alongside clinical validity whilst screening for depression (Topp et al., 2015). The existence of normative data is helpful for future population comparisons. Topp et al. (2015) demonstrate the utility and validity of the WHO-5 tool for measuring wellbeing across applied study fields using five simple and non-invasive questions. Due to its brevity, the WHO-5 is a useful tool for the regular monitoring of wellbeing in the applied sporting field where time constraint is a concern.

1.5 Research rationale and thesis questions

Availability to train and compete is a key component in the life of an athlete. However, the role of availability within the talent development process is poorly understood. The present thesis aimed to advance understanding of athlete availability in the talent development process of developing elite athletes by answering the following three research questions.

1. How does athlete availability and the determinants of athlete availability differ between NF and developing elite athletes?
2. What are the important determinants of athlete availability in an elite athletic population?
3. How important is athlete availability, sleep, wellbeing and health for talent development and progression?

A secondary aim of this thesis was to establish the determinants of athlete availability in developing elite athletes, by developing a new multidimensional athlete-monitoring tool that can assess the important determinants of athlete availability in developing elite athletes.

1.6 Thesis structure

The thesis is presented as a series of five chapters. Chapters 2 and 3 have been written as standalone papers that are in an appropriate format for journal submission. Whilst steps have been taken to minimise overlap and repetition, at times some repetition is necessary. Such an approach is consistent with the policy of the School of Human and Behavioural Sciences.

- The aims of Chapter 2 were threefold: 1) to compare availability, health, sleep, wellbeing and training of developing elite (DE) and NF athletes (NF), and examine whether athlete availability might be identified as an important factor in athlete development, 2) validate a new athlete monitoring questionnaire, and 3) to provide initial normative values for the athlete monitoring questionnaire for both developing elite and NF athletes.
- The broad aim of Chapter 3 was to identify what combination of variables best discriminated between athletes with lower and higher training availability (relating to health and training modification) in a cohort of developing elite swimmers using pattern recognition analyses.
- Chapter 4 was written as an executive report produced for Swim England and British Swimming. This empirical study aimed to identify the combination of training and health (biopsychosocial, training and health) factors that were important to discriminate between higher potential - high-level athletes, who were identified as most likely to progress in the high-performance system and lower potential athletes – high-level athletes less likely to progress in the high-performance system.
- Chapter 5 discusses the theoretical and applied implications of the current thesis.
- The appendix includes additional data, feedback presentations, individual reports and conference posters exemplifying the impact the P2P project has had so far in the applied world. Some additional documents are not presented in the appendix considering thesis length; however, they are readily available on request. Supplementary information is presented in the appendices

Chapter 2: The importance of multidisciplinary monitoring in athlete availability and talent development: a comparison of age-matched non-funded and elite developing athletes training, recovery, sleep, psychological stress, wellbeing, injury, and illness.

2.1 Abstract

It is unclear whether availability, training, sleep, stress, wellbeing, and health differ between age-matched non-funded (NF) and developing elite (DE) athletes and therefore potentially important determinants of athlete availability and development. The primary focus of this study was on the comparison between age-matched NF and DE athletes, which represent various stages of the talent development continuum, to ascertain if availability differs, and consequently might be identified as a crucial factor in athlete development. Our secondary focus sought to examine other outcome variables that might explain a (lack of) difference in availability. Using the Athlete Monitoring Questionnaire (AMQ), a weekly online tool that monitors the availability, training, sleep, recovery, stress, wellbeing and health of all athletic abilities and sports, I compared differences between high-level developing elite athletes (DE athletes; *n* = 42 from the Great Britain Olympic pathways of rowing, swimming, canoe sprint and canoe slalom) and NF athletes (NF; *n* = 79) over a 14-week data collection period. Results suggested that DE athletes were more available to train and compete compared to NF. Weekly training hours were greater and perceived effort was higher in DE athletes than NF (*M= 17.1, SD= 5.1 vs M= 6.0, SD= 3.2,* and *M= 5.8, SD= 1.2 vs M= 4.5, SD= 1.5*). Training volume reduction was lower in DE athletes, and DE athletes were also able to complete a greater portion of training and competition activities without health problems. Despite the higher training volume, DE athletes reported similar levels of recovery, higher readiness to train, greater total of 24 h sleep, higher wellbeing, and lower stress and had fewer injuries than NF. The injuries experienced by DE athletes were less severe with fewer training days lost than in NF. There was no difference in the prevalence of illness or days lost due to illness. Across the sample, AMQ response rates were high (*M* = 79%, *SD* = 11%) and completion times were short (*M* = 4 minutes 41 seconds, *SD* = 2 minutes 20 seconds). Taking the findings in concert, DE athletes were more available to train and compete in part due to better recovery including more sleep, lower psychological stress, better wellbeing, fewer less severe injuries, and days lost to injury. Thus, this study provides preliminary evidence that availability, sleep, psychological stress, wellbeing, injury prevalence and severity might be important in talent identification and development. Consequently, researchers and applied practitioners in talent identification and development should consider regular multidisciplinary monitoring with the AMQ.

Keywords: *Training, athlete monitoring, questionnaire, health, athletes, availability*

2.2 The importance of multidisciplinary monitoring in athlete availability and talent development

Athlete availability is the extent to which an athlete can complete their prescribed training to an optimal standard and has been associated with successful performance (Hagglung et al., 2013; Podlog et al., 2015; Raysmith & Drew, 2016). The consequences of (un)availability are profound. Not only can (un)availability negatively affect the game, match, or competition performance (Raysmith & Drew, 2016), but availability also conduces to wider economic and societal implications such as the reductions in funding available to athletes and sporting organisations because of relegation or failure to qualify for major events that offer revenue-building opportunities (Stewart, 2017). That said, it is unclear whether availability and the associated consequences differ between athletics levels (e.g., non-funded (NF) and developing elite (DE) athletes). Given the focus of the literature on elite adult athletes' availability (Hagglung et al., 2013; Podlog et al., 2015; Raysmith & Drew, 2016), understanding of availability at other sporting levels (e.g., young athletes developing toward elite status or NF athletes) is limited. Practitioners and athletes from these different levels are currently basing their understanding of availability on principles that are not necessarily comparable to their age or sporting level.

Given the potentially profound consequences of availability on performance, it is also worth considering the effect of availability on athletic development (i.e., the ability of an athlete to transition through the high-performance pathway). Over the years, an abundance of research has investigated determinants of athletic development in the attainment of world-class success (Rees et al., 2017). Yet, research has failed to examine the implications of athlete availability on athletic development. This is perhaps due to availability being an accepted characteristic of a high-performing athlete considering that elite athletic performance is partly attributed to the volume, specificity and variability of training accumulated over an athletes' career (Güllich & Emrich, 2014; Rees et al., 2016). One such view is that an individual can only become an expert in each field with sufficient engagement in domain-specific deliberate practice (i.e., effortful, goal-orientated focused practice; Tucker & Collins, 2012). Therefore, it would stand to reason that being available to train and compete (without modifications due to health problems) would be important in athletic development. However, because little is known about the difference in the availability of age-matched NF and DE athletes, we cannot be certain of the importance of availability in athletic development.

2. 21 The need for an appropriate monitoring tool

Existing approaches to assessing factors that may contribute to athlete availability cover a broad spectrum of training, recovery, stress, wellbeing, sleep, injury and illness variables (Bittencourt et al., 2016; Gabbett, 2016). Over the years, sports have adopted techniques for monitoring such variables. For example, global positioning systems (GPS) offer a valid and reliable measure of training volumes (i.e., distance, velocity, time in zones, and acceleration; Coutts & Duffield, 2010). Similarly, subjective markers of recovery and stress such as the REST-Q for athletes (RESTQ-Sport; Kellman & Kallus, 2001) have received mounting interest within sport (Jones et al., 2017). A detailed review of the available markers can be found in Chapter 1. From this review, it is evident that several limitations are evident regarding the majority of the extant availability monitoring tools. The multitude of extant indicators of (un)availability is varied. Thus, to gain a holistic and comprehensive understanding of an athletes' response to training, practitioners need to assess multiple constructs as opposed to simply relying on any one approach. The combined use of appropriate validated measures, however, means that the collection, analysis, and interpretation of data becomes a resource-intensive process both for athlete and coach, often leading to poor adherence from all parties, making for unreliable data. Accordingly, applied practitioners are now using custom-made versions of monitoring measures to document the multidisciplinary nature of athlete availability. Tools such as SmartaBase© (https://www.fusionsport.com/smartabase/) and Metrifit© (https://metrifit.com/) are just two of the custom-made platforms available. However, many come with a cost attached. Further, these measures are tailored toward specific populations (e.g., elite athletes) and therefore may not be suitable across all athletic levels. To our knowledge, a comprehensive approach to athlete monitoring that is valid and reliable, yet also efficient does not exist in the scientific and applied practice literature, especially across *all* athletic abilities. In the present study, we developed the Athlete Monitoring Questionnaire (AMQ), a weekly measure of training volume, sleep, wellbeing, stress, recovery, and injury and illness. Given the lack of research within NF and DE populations, there is a need to investigate the availability, training, sleep, stress, wellbeing and health differences between age-matched NF and DE athletes and therefore potentially important determinants of athlete availability and development.

2.22 Hypotheses

Firstly, we hypothesised that DE athletes complete greater training volumes than NF, as elite sporting performance is partly attributed to the volume, specificity, and variability of training (Rees et al., 2016). Secondly, given the growing evidence suggesting that elite athletes obtain insufficient sleep quality and quantity due to early morning training schedules (Sargent et al., 2014), we expected DE athletes to report poorer sleep quality and quantity in comparison to NF. Third, as sleep influences wellbeing (Purcell et al., 2019), we hypothesised that DE athletes would report lower wellbeing levels. Fourth, we expected DE athletes to report increased stress levels in comparison to NF, due to the demands of the pathway-training environment and the associated organisational stressors (Woodman & Hardy, 2001). Fifth, we expected differences between DE athletes and NF around illness, injury, and health. On one hand, regular, prolonged, and intense exercise is associated with an increased risk of infection (Walsh et al., 2011). However, evidence also suggests that *high-achieving* athletes can withstand such training volumes without a consequential increase in infection rates (Malm, 2006). Similarly, the relationship between training volume and injury is equivocal considering the evidence for both higher (Hulin et al., 2014) and lower (Gabbett, 2016) rates following increased training volumes. Therefore, given the contrasting evidence, we refrained from making a directional hypothesis. Altogether, these support our overarching hypothesis whereby the expected high training volume, poor sleep behaviours, low wellbeing and high stress of DE athletes lead them to be less available than NF.

2.3 Method

2.31 Participants

The study received institutional ethics approval from Bangor University (P10-18/19) on 18th December 2018. Recruitment occurred between 2018 and 2020 UK Sport and English Institute of Sport staff approached podium potential squads of various Olympic sports to request participation. As a result, 42 podium potential athletes (hereafter *DE athletes;* 17 male, 25 (60%) female; M_{age} = 21.0; *SD* = 2.5) consented to participate. DE athletes came from four Olympic National Governing Bodies (NGBs): British Rowing (*n* = 13), Swim England (*n* = 16), British Canoe Slalom (n = 8) and British Canoe Sprint (n = 5). All DE athletes were part of a UK sport funding national governing body programme. We also recruited 79 age-matched (p=0.762) NF British Universities and College Sport (BUCS) athletes (, NF; 23 male, 56 (71%) female; M_{age}= 21.2; *SD* = 2.8) to participate (see Appendix 2.1). We excluded NF participants if they considered themselves sport-contracted, semi-professional or professional athletes. Both NF and DE athletes provided written informed consent.

2.32 Measures

2.321 The Athlete Monitoring Questionnaire

The Athlete Monitoring Questionnaire (AMQ; Appendix 3.1) is a weekly application tool used to monitor several physiological and psychological factors in minimal time, using validated measures, and with high athlete adherence. The AMQ measures training and competition availability, training volumes, sleep, wellbeing, stress, and health (injury and illness). These variables were deemed essential determinants of recovery, and injury and illness prevention (Bourdon et al., 2017; Saw et al., 2016).

A weekly rather than daily completion minimised athlete burden as athletes are known to dislike paperwork (Beckmann & Kellmann, 2003). With a maximum of 23 questions, we designed the AMQ to be completed in approximately five minutes. The questions comprising the AMQ are either exact or slightly modified versions of existing validated monitoring measures (see Table 2.1 and Chapter 1 for a description of measures used). Where items required modification, it was about altering the period for the response (e.g., changing from two weeks to one week) meaning that item content remained identical to the original. We selected questions from validated measures based on item relevance, and comprehensibility (Horvath & Röthlin, 2018).

Table 2.1 ***Overview of AMQ variables and the validated measures***

Variable	Chosen validated measure
Training volume: Training/competition duration and distance	Self-reported training/competition hours and sport-specific distances if appropriate
Internal load: Perceived exertion	Rating of Perceived Exertion (RPE; Borg, 1998)
Readiness to train	(Pruscino et al., 2013)
Perceived recovery	Perceived Recovery Scale (PRS; Laurent et al., 2011)
Perceived stress	Perceived Stress Scale 4 item (PSS-4; Cohen, Kamarck & Mermelstein, 1983)
Wellbeing	WHO-5 (Topp et al., 2015; WHO, 1998)
Health – Injury & Illness – Prevalence – Severity – Relative impact on training/performance	Oslo Sports Trauma Research Centre Questionnaire - health problems (OSTRC-HP; Clarsen et al., 2014)
Sleep - Sleep hours (nighttime only & within 24 hour period which includes napping duration and frequency) - Daytime napping duration and frequency - Sleep quality and latency	Questions selected from Pittsburgh Sleep Quality Index (PSQI: Buysse et al., 1989) and the Athlete Sleep Screening Questionnaire (ASSQ; Samuels et al., 2016)

2.33 Procedures

The study received institutional ethics approval (P10-18/19) on 18th December 2018. Participants completed the AMQ for 14 weeks from October 2019 to February 2020 using commercially available computer software (Qualtrics, 2009). Each participant received an individualised link to the questionnaire weekly via email and/or text. Researchers supervised all participants during the first week of completion to ensure understanding and accuracy of responses. A 48-h completion window prohibited data from one-week altering responses from another. Non-responders received a reminder after 24 h and 48 h. Once the completion window had closed, researchers downloaded the data and generated a weekly feedback document. DE athletes received a 12-week longitudinal rolling report via email. Nominated coaches and support staff of the DE athletes also had the option to receive their respective athlete's feedback. With athletes' consent, the head coach and lead support staff received a simplified group summary of their squad so that health problems or 'red flags' could be addressed with the appropriate support. The NF population were able to access similar feedback via a personalised login to a platform created using R (R Core Team, 2017).

2.4 Data analysis

2.41 Statistical analyses

We analysed all data using SPSS statistical software (IBMCorp. Released 2016. IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp). We used independent *t-tests* to analyse between-group differences (NF and DE athletes) and calculated effect sizes (ES) using Cohen d, where 0.2 represented a small effect size, 0.5 a medium effect size, and 0.8 a large effect size (Cohen, 1988).

2.42 Prevalence.

To calculate the prevalence of all health problems, injuries, and illnesses for any given time point over the 14-week study period, we followed the methodology previously used and described in detail by Clarsen et al. (2013). In brief, we calculated the prevalence as the total number of health problems reported by each athlete and divided this value by the number of AMQ weeks completed[1]. We calculated the group prevalence by dividing the sum of the athlete averages by the number of athletes. In line with Clarsen et al. (2013), we calculated the prevalence for each of the four questions (participation, training volume reduction, sports performance reduction, and symptom experience) at three different levels. These are defined in Table 2.2. We present all prevalence measures as means (SD), together with a 95% confidence interval (CI).

Table 2.2. Prevalence and severity of health problems in line with Clarsen et al., (2013)

Prevalence Level of Health Problems	Definition
Level 1 (no health problems)	Defined as (no) problems as the absence of health problems reported with full participation without health problems, no reduction in training volume or sports performance, or no symptoms experienced
Level 2 (mild health problems)	Defined as the presence of health problems that led to a mild reduction in training volume or sports performance, or mild symptoms experienced
Level 3 (substantial health problems)	Defined as those leading to moderate or severe reductions in training volume, or moderate or severe reductions in sports performance.

[1] *The absence of data where athletes did not complete the AMQ does not indicate whether an athlete had or did not have a health problem. Thus, we only considered weeks where athletes completed the AMQ. As an example, if an athlete completed the AMQ for seven of the 14 weeks, and reported a health problem in each of those 7 weeks then the prevalence of health problems for that athlete was calculated at 100%. However, an athlete who completed the AMQ every week for 14 weeks but reported a health problem in seven weeks would have a prevalence score of 50%.*

2.43 Severity

To assess severity, we used Clarsen et al.'s (2013) method and scored the response to each of the four key questions (participation, training volume reduction, sports performance reduction, and symptom experience) from 0 to 25, where 0 represents no problems and 25 represents the maximum level for each question (see Table 2.3). We then summed the scores of each question to calculate a severity score ranging from 0 to 100 for each health problem. We also calculated the cumulative severity score for each case by summing the severity score for each week that the same health problem was reported. Finally, we calculated the average weekly severity score by dividing the cumulative severity score by the number of weeks the problem was reported.

Table 2.3. Scoring system of the health questions (Clarsen et al., 2013)

Question	Score
Question 1: Have you had any difficulties participating in normal training and competition due to injury, illness, or other health problems during the past week?	
Full participation without health problems (injury/illness)	0
Full participation, but with injury/illness	8
Reduced participation due to injury/illness	17
Cannot participate due to injury/illness	25
Question 2: To what extent have you reduced your training volume due to injury, illness, or other health problems during the past week?	
No reduction	0
To a minor extent	6
To a moderate extent	13
To a major extent	19
Cannot participate due to injury/illness	25
Question 3: To what extent has injury, illness or other health problems affected your performance in training during the past week?	

No effect	0
To a minor extent	6
To a moderate extent	13
To a major extent	19
Cannot participate due to injury/illness	25
To what extent have you experienced symptoms/health complaints during the past week?	
No effect	0
To a minor extent	8
To a moderate extent	17
To a severe extent	25

2.5 Results

2.51 AMQ utility: response rate and completion times

DE athletes and NF had a mean response rate of 79% (11%) and a completion time of 04:41 (02:20, m m:ss).

2.52 Availability, injury, and illness

An average of 26% of the DE athletes and 42% of the NF experienced health problems (see Table 2.4). Of these health problems, 38% reported by DE athletes and 25% by NF were considered substantial. DE athletes were available to participate fully in weekly training and competition 16.7% more of the time than NF (Question 1, 73.9% versus 57.2% Table 2.4). Further, DE athletes reported fewer injuries compared to NF. Only 13.5% of injuries reported by DE athletes were substantial and thus, caused significantly fewer days lost in comparison to those experienced by NF. There was no difference, however, in the prevalence of illness or days lost due to illness (Table 2.4). In summary, DE athletes reported greater availability and fewer overall health problems than NF but both groups reported a similar prevalence of illness.

Table 2.4 ***Comparison of DE athletes to NF for characteristics of monitoring health problems over 14 weeks.***

Variable	**DE athletes (*n* = 42)**	**NF athletes (*n* = 79)**	***t* (df)**	**p**	**Effect Size**
Prevalence of all health problems (%)	25.6 (21.5)	42.2 (33.6)	-3.3(115)	0.001*	0.6
Injuries (%)	7.9 (15.1)	22.1 (29.8)	-3.5(119)	0.001*	0.6
Illnesses (%)	17.8 (14.7)	20.1 (27.3)	-0.6(119)	0.547	0.1
Substantial health problems (%)	38.1 (31.4)	24.9 (34.2)	1.9(103)	0.057	0.4
Injuries (%)	13.5 (28.9)	42.4 (38.5)	-3.1(31)	0.004*	0.8
Illnesses (%)	51.9 (36.0)	43.8 (41.2)	0.9(84)	0.352	0.2
Severity (per health problem, out of 100)	40.9 (13.2)	42.0 (14.5)	-0.4(103)	0.688	0.1
Injuries	22.0 (8.7)	36.5 (13.1)	-4.0(61)	0.000*	1.3
Illnesses	48.4 (16.3)	46.0 (19.3)	0.6(84)	0.559	0.1
Average days lost per athlete due to health problems	4.0 (4.7)	5.8 (8.8)	-1.4(119)	0.150	0.3
Injuries	0.4 (1.5)	2.5 (6.6)	-2.6(93)	0.010*	0.4
Illnesses	3.6 (3.8)	3.3 (6.3)	0.3(119)	0.784	0.1
Question 1: Participation					
Full participation in training/competition without health problems (%)	73.9 (21.5)	57.2 (33.5)	3.3(115)	0.001*	0.6

Full participation in training/competition with health problems (%)	10.6 (15.6)	23.0 (26.5)	-3.2(118)	0.002*	0.6
Reduced/cannot participate in training/competition (%)	15.5 (12.4)	19.8 (24.1)	-1.3(119)	0.207	0.2
Question 2: Training Volume					
No training volume reduction (%)	79.6 (16.4)	67.2 (28.3)	3.1(118)	0.003*	0.5
Mild training volume reduction (%)	11.2 (10.4)	15.8 (17.2)	-1.6(119)	0.117	0.3
Substantial training volume reduction (%)	9.2 (9.3)	17.0 (22.5)	-2.7(114)	0.008*	0.5
Question 3: Sports Performance					
No sports performance reduction (%)	75.5 (22.3)	62.2 (31.8)	2.7(110)	0.009*	0.5
Mild sports performance reduction (%)	14.8 (14.6)	18.5 (19.3)	-1.1(119)	0.28	0.2
Substantial performance reduction (%)	9.7 (11.5)	19.3 (24.7)	-2.9(118)	0.005*	0.5
Question 4: Symptoms					
No symptoms (%)	72.6 (20.8)	58.3 (31.9)	3.0(114)	0.004*	0.5
Mild symptoms (%)	17.3 (13.0)	20.3 (20.1)	-1.1(119)	0.279	0.2
Substantial symptoms (%)	10.1 (12.2)	21.4 (26.8)	-3.2(117)	0.002*	0.5

*Some data are presented as means (standard deviations). *Significant difference between DE athletes and NF ($p < 0.05$). Abbreviations: Severity = cumulative severity score for each week health problem is recorded / number of weeks health problem lasts.*

2.53 Training outcomes

DE athletes trained and competed substantially more each week than NF (see Table 2.5). DE athletes also reported higher perceived effort. Despite this greater volume of training and effort, DE athletes reported greater readiness to train than NF, with both groups reporting similar levels of perceived recovery (Table 2.4).

Table 2.5 ***Comparison of DE athletes to NF for training variables***

Variable	DE athletes (n=42)	NF (n=79)	*p*	*t (df)*	Effect Size
Weekly training and competition volume (hours)	17.1 (5.1)	6.0 (3.2)	0.000*	12.9(59)	2.6
RPE (weekly)	5.8 (1.2)	4.5 (1.5)	0.000*	4.7(119)	0.9
Perceived recovery	6.4 (1.2)	6.1 (1.8)	0.181	1.3(114)	0.2
Perceived readiness to train	3.7 (0.7)	3.4 (0.7)	0.028*	2.2(119)	0.4

*All data are presented as means (standard deviations). * Significant difference between DE athletes and NF (P < 0.05). Abbreviations: RPE, Ratings of Perceived Exertion, where 0 = at rest, 10 = maximal; Perceived recovery: 0 = very poorly recovered, 10 = very well recovered; Perceived readiness to train: 0 = at no time, 5 = all the time.*

2.54 Sleep, stress, and wellbeing

DE athletes went to bed and woke up earlier and napped more than NF (Table 2.6). Thus, DE athletes slept more than NF in 24 hours. DE athletes also reported significantly better sleep quality than NF. However, both DE athletes and NF reported that they experienced a sleep latency of greater than 30 minutes and sleep disturbance on more nights than they did not (Table 2.6). DE athletes reported significantly better wellbeing and lower stress than NF (Table 2.6).

Table 2.6. ***Comparison of DE athletes to NF for characteristics for sleep, stress, and wellbeing.***

Variable	DE (n=42)	NF (n=79)	p	*t (df)*	Effect Size
Total daily sleep (hh: mm)	07:51(00:44)	07:25 (01:02)	0.016*	2.5(119)	0.5
Night sleep (hh: mm)	07:31 (00:50)	07:12 (01:00)	0.073	5.6(119)	1.1
Waketime (hh: mm)	06:18 (00:58)	08:57 (01:15)	0.000*	-11.9(119)	2.4
Bedtime (hh: mm)	22:09 (00:38)	24:00 (01:30)	0.000*	-9.4(115)	1.6
Napping duration (hh: mm)	00:54 (00:31)	00:43 (00:30)	0.045*	2.0(119)	0.6
Napping days per week	1.6 (1.1)	1.1 (1.0)	0.01*	2.6(119)	0.5
Fairly/very-bad sleep (%)	13.0 (20.0)	27.0 (30.0)	0.003*	-3.1(113)	0.6
Extended sleep latency (%)	53.0 (36.0)	69.0 (32.0)	0.014*	-2.5(119)	0.5
Sleep disturbance (%)	68.0 (34.0)	69.0 (33.0)	0.95	-0.01(119)	0.01
Average perceived stress score (out of 16)	4.6 (2.6)	6.3 (2.5)	0.0010*	-3.4(118)	0.6
Average wellbeing score (%)	68.0 (15.0)	56.0 (16.0)	-	-	-

*Data presented as means (standard deviations). * Significant difference between DE and NF athletes (P < 0.05). Abbreviations: Total daily sleep, average total sleep reported within 24 hours – including napping durations distributed across the week; Sleep latency (%), percentage of weeks where athletes reported that on one night or more per week they were unable to sleep within 30 minutes; Sleep disturbance (%), percentage of weeks where athletes reported that on one night or more per week they woke up in the night.*

2.6 Discussion

This study explored differences between the availability of DE athletes and NF, with the expectation that DE athletes would report lower levels of availability (as indexed by our various measures). Our findings indicated that DE athletes had fewer problems with injury, although illness prevalence was similar across groups. Further, DE athletes completed larger training and competition loads than NF and reported greater levels of effort (confirmation of hypothesis 1). Despite this increased load and in contrast to hypotheses 2, 3 and 4 DE athletes reported similar levels of recovery, greater levels of perceived readiness to train, greater quantity and quality of sleep, greater wellbeing, and lower stress levels. Considering these findings in their totality, two points are evident. First, in contrast to our overarching hypotheses, according to our data, DE athletes appear more available than NF. Secondly, the AMQ has considerable utility as a measure of explaining factors associated with athlete availability across different athletic populations. Across the data collection period, adherence to the AMQ was remarkably high and completion time was approximately five minutes per week. Thus, for minimal effort, athletes and practitioners can glean substantial amounts of information regarding training, health and injury status, variables that might differ between athletic populations and may explain the availability differences.

2.61 Availability, injury, and illness

DE athletes were more available to train without health problems than NF. The improved recovery including more sleep, lower psychological stress, better wellbeing, fewer and less severe injuries, and days lost to injury reported by DE athletes could explain the greater athlete availability.

The average weekly prevalence of health problems reported by DE athletes was considerably lower than in NF. Despite the higher prevalence of health problems reported by NF, 23% of NF (compared to 10.6% of DE athletes) reported that they were available to complete training with no modifications even with a health problem. However, it is apparent from the other AMQ variables that NF had a lower recovery, higher psychological stress, lower wellbeing, and completed lower weekly training volumes at a lower perceived effort compared to DE athletes. Thus, the presence of a health problem, even if it appears not to affect training, could have a detrimental effect on the individual. Alternatively, the findings of the other AMQ variables could be a consequence of training as 'normal' with a health problem (i.e., training through the health problems). As such, NF perceives they can continue training with a health problem without modifications, but the other AMQ variables indicate the individual is suffering in other ways (poor recovery, poor sleep, and higher stress). This finding provides further support for the need to measure availability holistically. Simply measuring availability alone does not provide the bigger picture of the holistic training state of an athlete.

The injury prevalence in DE athletes (7.9%) was consistent with literature from elite junior athletes (e.g., Pluim et al., 2016) yet was considerably lower than in professional and Olympic athletes, where studies have reported weekly injury prevalence between 36 and 40% in Olympic and professional athletes (Clarsen et al., 2014; Nordstrøm et al., 2020). The greater injury prevalence in NF (22.1%) could be due to poor management of training and inadequate recovery (Bourdon et al., 2017). DE athletes in this project received support and regular education on load management, sleep hygiene, and injury and illness prevention. It is unlikely that the NF received similar support; thus, the increased injury rates could be attributable to poor training behaviours.

Based on the J-shaped (Nieman, 1994) and S-shaped curve (Nielsen, 2013) illness hypotheses, there is evidence to suggest there is a beneficial relationship between exercise and immunity in NF and elite athletes, respectively. Therefore, we expected illness prevalence to be low in both DE and NF. Conversely, the weekly prevalence of illness at any given time in both DE athletes (18%) and NF (20%) athletes were higher than in other work (13%, Clarsen et al., 2014; 6%, Nordstrom et al., 2020). The most common symptoms reported were breathing difficulties (18%), cough (10%), sore throat (9%), blocked/running nose (9%), and headache (8%), all of which are associated with a respiratory infection (Jackson et al., 1958). Our data collection period (which involved the UK autumn and winter) could explain these differences as influenza incidence exhibits seasonal fluctuations with a peak in autumnal and winter months (Walsh, 2018).

2.62 Sleep

DE athletes reported longer sleep durations and better sleep quality than NF despite significantly earlier wake time, with both groups meeting the recommended sleep duration guidelines for the general population (Hirshkowitz et al., 2015). The sleep quantity reported by DE athletes is surprising considering that previous literature has found elite athletes tend to neglect sleep as a recovery tool (Leeder et al., 2012; Sargent et al., 2014). Thus, this study highlights the importance of napping for DE athletes as napping was more frequent and for a longer duration than for NF. As discussed elsewhere in the literature (Walsh et al., 2020), daytime napping can be used to supplement limited night-time sleep (i.e., those that have rigid early training times).

2.63 Wellbeing and stress

DE athletes reported higher wellbeing and lower stress than NF. DE athletes reported similar levels of wellbeing to those found in the UK general population (DE athletes = 68%, NF = 56%, general population = 66%; Randall et al., 2019) but higher levels when compared to a young elite athletic sample (58%; Ohlert & Ott, 2017). Further, DE athletes reported considerably lower stress than NF but had similar stress levels as the English general population (DE athletes = 4.64, NF = 6.3, general population = 6.11; Warttig et al., 2013). These findings suggest that contrary to the view that some aspects of elite sport increase the risk of poor mental health (Lebrun & Collins, 2017), being part of the performance pathway has a positive impact on mental health, at least in terms of the factors measured here. The higher wellbeing and low stress of DE athletes coupled with improved sleep are likely indicative of adequate recovery. Further, wellbeing has been reported to impact the training output of individuals (Gallo et al., 2016) thus, the higher weekly training volumes and perceived effort coupled with the greater perceived recovery and greater readiness to train of DE athletes compared with NF could be attributable to the self-reported high wellbeing and low stress.

2.64 Implications

Collectively, the differences and similarities identified between DE athletes and NF help to identify which factors are/are not important determinants of athlete availability. Due to the level of data collected, we can conclude that DE athletes are more available than NF. DE athletes can complete high weekly training volumes at a higher perceived effort but with a low prevalence of injuries. We found that DE athletes demonstrate better wellbeing, lower stress, greater sleep duration, better sleep quality, greater perceived recovery, and greater readiness to train than NF. Overall, these data suggest that performance pathways, or at least the athletes sampled here, are managing their DE athletes well, and as such, do not seem to be as susceptible to consequences associated with the pressures of elite sport. That said, DE athletes, NF and coaches are still able to learn from these data. The perception that illnesses were more severe than injuries could explain the greater loss of training days due to illness in comparison to days lost due to injury. Given the impact of respiratory illness on the availability of both DE athletes and NF, there is a requirement for action, particularly education on strategies to prevent illness. To limit respiratory infections, Walsh (2018) offers recommendations regarding training, sleep, psychological, environmental, and nutritional related factors. For example, to reduce the likelihood of infection athletes should ensure good hand hygiene (washing hands regularly and thoroughly), avoid sick people, carefully manage increments in training stress, allow for adaptation training weeks and eat a well-balanced diet (Walsh, 2018).

From a wider perspective, the differences and similarities identified within this study may help to identify which factors are/are not important (e.g., training, sleep, psychological stress, wellbeing, and injury, but not illness) regarding athlete development and progression from lower to prominent levels of achievement. This point assumes that DE athletes and NF represent various stages along the talent development continuum. The findings also provide evidence that these factors should be considered in future research that aims to investigate talent development. Although the factors were identified as important to differentiate between DE athletes and NF, this does not mean that these same variables will be important determinants of athlete availability and progression through the performance pathway *within* a group of DE athletes. Therefore, a different approach to the analysis of these data (such as including all variables in one model with development status as a covariate and availability as an outcome) may be warranted. Hence the need for further research.

At a broader level, given that the important discriminatory factors were a mixture of training, recovery, sleep, and physical and psychological wellbeing, effective monitoring of athlete availability needs to be multidisciplinary, hat the AMQ is well suited for this purpose. Indeed, the differences that we obtained between our two groups provide additional evidence to support the AMQ's validity. Specifically, given the difference in expertise between DE athletes and NF, we expected differences between certain factors on the AMQ. These included training hours, wellbeing, health problem prevalence and sleep duration. Our hypotheses were largely supported, which helps to provide validity for the AMQ beyond initial face/content validity.

2.65 Limitations

Despite the clear findings, some limitations are noteworthy. We utilised a cross-sectional study design, as these are useful in establishing preliminary evidence (Wang & Cheng, 2020) and are easy to conduct in populations where time is limited. However, a cross-sectional design only provides data at a single time point therefore, we cannot determine causality in our findings. Future research using multiple seasons, or a repeated-measures study design would overcome this limitation yet, this would require researchers to follow athletes throughout their sporting career (i.e., from recreation to developing elite to elite) which may take anything from 10-15 years. A longitudinal study of this nature is not feasible within a typical 4-year PhD timeframe.

Due to previous monitoring tool issues regarding utility, adherence, and comprehensiveness, we decided to use shortened validated measures reflecting a week-long period in the AMQ. Although we engaged in a rigorous process of measure and item selection (and adaptation where required) some of the measures may be more susceptible to recall bias across a week, as opposed to more immediate (i.e., daily) ratings. While we acknowledge that daily ratings certainly have benefits for a recall, we note that, given athletes' dislike of paperwork (Beckmann & Kellmann, 2003), increasing the requirements for athletes in terms of completion would lead to substantially reduced adherence rates, making a daily approach somewhat worthless. Additionally, whilst our findings provide some evidence of validity in the sampled populations, they remain limited to the (few) sports used. There would be considerable benefit in extending this work to more sports to further enhance the generalisability of the findings.

We also believe that further revision to the AMQ would be worthwhile. In the current version, the sleep data did not discriminate between training and rest days. It is worth considering differences in sleep durations throughout a typical training week. Sleep duration before a training day (with an early start) is likely to be much less than a rest day however, at present the AMQ does not account for the discrepancy between these two days. This is of interest to practitioners considering recent evidence suggests that 'sleep banking' (i.e., getting more sleep in anticipation of sleep loss) may enhance performance (Arnal et al., 2016; Vitale et al., 2019). In addition, collecting detail regarding the intended and actual days of training per week and the reason for any discrepancy would add accuracy to implications of days missed due to health problems. Thirdly, an athlete should be able to report alternative reasons for unavailability to train such as holidays, family, work, or school commitments.

We acknowledge that the success of this measure is dependent on athlete adherence. However, we acknowledge that the inclusion of feedback may have affected athletes' subsequent response but this was deemed necessary for adherence. Anecdotal evidence suggested that adherence was better in those with coach/ support staff engagement who received and utilised the weekly feedback forms. We therefore would encourage the use of regular feedback to athletes, the recruitment of coaches/support staff and more importantly, the education on how to best utilise the AMQ (and feedback) in future use within the applied setting. Further research may look to include a control group that did not receive feedback as to establish the effect on the results.

2.66 Concluding remarks

In comparison with age-matched NF, DE athletes were more available to train and compete in part due to better recovery including more sleep, lower psychological stress, better wellbeing, fewer, less severe injuries, and days lost to injury. This study provides preliminary evidence that availability, sleep, psychological stress, wellbeing, injury prevalence and severity might be important in talent identification and development. Although we only have data from four sports, the data suggest that these sporting pathways are managing their athlete's training, wellbeing, and health well. Relatedly, we are only able to draw these conclusions because of the AMQ and its ability to measure multiple variables. Further, this exploration has provided normative data for validated measures in both developing-elite and NF athletes. Whilst the AMQ appears to represent an incredibly useful measure of athlete availability, sports practitioners and athletes would benefit from a greater understanding of the exact determinants of athlete availability thus, further research exploring the precursors of availability using the AMQ will help to increase understanding in this key aspect of sports performance. Consequently, researchers and applied practitioners in talent identification and development should consider regular multidisciplinary monitoring with the AMQ.

Chapter 3: Establishing the determinants of Athlete Availability in Developing Elite Swimmers: A pattern recognition approach

3.1 Abstract

In the present study, we applied a holistic approach to identify the combination of factors that best discriminated between the ability of developing elite swimmers to participate in training without modifications or health problems over an extended period. Fifteen developing elite swimmers (19.2 ± 1.7 years old; 9 females, 6 male) completed the Athlete Monitoring Questionnaire (AMQ) weekly, via an online platform, for 62 weeks (November 2019 – January 2021) reporting their training and competition availability, training volumes, sleep, wellbeing, stress, and health (injury and illness). Pattern recognition analyses revealed that from a possible 152 features, a subset of 10 features reliably discriminated between athletes who were able to participate in training without any health problems and a subset of 15 factors that discriminated between those more or less available to participate in training without any modification to training due to health problems. Swimmers who were more available to train completed higher volumes of training had better health (lower prevalence of health problems, higher wellbeing, and lower psychological stress), and experienced better quality night-time sleep (i.e., could fall asleep within 30 minutes more often and did not wake up at night as frequently). These findings identify that athlete availability is not determined through unidimensional constructs; rather availability is best understood via a multidimensional approach, which considers (at least) training hours, sleep, and wellbeing. This study is the first to apply both a multidimensional approach to its data collection methods and its analyses. This study highlights that practitioners wanting to improve athlete availability might do so by improving sleep quality and wellbeing, and reducing psychological stress

Keywords: Athlete monitoring, health, swimming, wellbeing, sleep

3.2 Establishing the determinants of athlete availability in Developing Elite Swimmers: A pattern recognition approach

The higher volumes of regular intense training required by elite athletes are associated with an increased health risk, such as injury and illness (Schwellnus et al., 2016; Soligard et al., 2016). Indeed, substantial injuries and illnesses affect an athlete's availability to complete their prescribed training to an optimal standard (Hägglund et al., 2013; Podlog et al., 2015). The consequences of injury or illness and a subsequent lack of athlete availability to participate in training are profound and can negatively affect game, match, or competition performance (Raysmith & Drew, 2016) and ultimately, may hinder the ability of an athlete or team to progress through their respective performance pathways. Availability, and more specifically the lack of availability to participate in training, can also carry an economic burden; organisations with unavailable athletes may encounter issues such as relegation or failure to qualify for the financially lucrative competition, and therefore lose considerable amounts of funding (Stewart, 2017).

Given the centrality of training availability to athletic performance and sports organisation success, research has attempted to negotiate the complex web of training availability determinants via athlete monitoring (Coutts et al., 2019). Existing research has established relationships between several athletic variables and injury/illness onset, thus identifying them as risk factors. For example, a dose-response relationship exists between training volumes undertaken by an individual and the subsequent incidence of injury (Drew & Finch, 2016; Hulin et al 2014) and illness (Hellard et al., 2015; Malm, 2006). Further, poor sleep is associated with an increased risk of injury and illness (Fox et al., 2020; Hamlin et al., 2019; Milewski et al., 2014; Walsh, 2018). Empirical evidence has also identified increases in both physiological and psychological stress as risk factors for injury and illness (Galambos et al., 2005; Ivarsson et al., 2017; Johnson & Ivarsson, 2017; Pensgaard et al., 2018). The provision of targeted prevention strategies such as good hygiene behaviours to minimise infection risk (Keaney et al., 2019) suggests that illness stressors are somewhat manageable. In contrast, injury prediction and prevention are much more complex, with research providing, at best, an estimation of the determinants of injury (Stern et al., 2020). Research surrounding the utility of athlete monitoring to aid athlete availability, particularly in the understanding and prevention of unavailability, has a long way to go.

One issue inherent within athlete monitoring is that the mono-disciplinary approach (i.e., exploring one or a limited number of variables in isolation) favoured by several previous studies (e.g., Drew & Finch, 2016; Fox et al., 2020; Ivarsson et al., 2017) fails to explain the multifactorial and complex nature of availability (Stern et al., 2020). The existing literature examining the impact of training and health-related variables on athlete availability (e.g., Drew et al., 2017; Raysmith & Drew, 2016) focuses predominantly on elite adult athletes and so, practitioners and developing athletes are currently basing their understanding of availability and monitoring on principles that are not comparable to their sporting level or goals. For example, sleep recommendations differ between age groups (teenagers = 8-10 hours, younger adults = 7-9 hours (Hirshkowitz et al., 2015). Hence, there is a need to examine the variables of the AMQ (e.g., training, health, sleep, wellbeing, and stress) and their relationships with availability within a developing elite population.

Accordingly, in Chapter 2 we developed and tested the Athlete Monitoring Questionnaire (AMQ) to compare the training and competition availability, training volumes, sleep, wellbeing, stress, and health (injury and illness) of non-funded (NF) and developing elite (DE) athletes. Ultimately, the AMQ can be used to holistically track progress towards athlete unavailability in an efficient, effective, valid, reliable, and comprehensive manner in various sporting contexts across all sporting abilities. We provided initial evidence for the validity of the AMQ by examining differences between NF and DE athletes over 14 weeks.

The results revealed that DE athletes were more available to train without health problems than NF athletes were. More specifically, compared to NF athletes, DE athletes completed higher volumes of training yet reported better sleep and wellbeing, and less injury and illness. The differences between NF and DE in availability, coupled with differences in training volumes, sleep, wellbeing, and stress, suggest that all these factors (sleep, health, wellbeing, and training) may be relevant in understanding athlete availability. Assuming that, compared to elite athletes, NF athletes are representative of less developed athletes at an earlier point on the talent development continuum, these data highlight that, as well as high training volumes, availability, sleep, injury, illness, and wellbeing, might be important determinants in the process of talent development.

Although these initial data are promising in relation to understanding the importance of athlete availability and its determinants (training volume, injury, illness, sleep, and wellbeing) on talent development, some key omissions remain. First, the data from Chapter 2 do not offer insights as to what variables are important to discriminate *within* the developing elite athletic group nor which *combination* of variables are most predictive of athlete availability. For example, developing elite athletes do more training than NF athletes; however, training hours may not discriminate between developing elite athletes that are available to train or not. As such, a detailed examination of factors influencing availability is needed. Second, the short data collection period (14 weeks) used in Chapter 2 is not representative of a full training season, and so an extended data collection period is needed to more fully understand the factors involved in athlete availability.

With the issues in mind, we took a comprehensive and longitudinal approach to examine the combination of factors that best discriminate between the training availability of developing elite swimmers across an extended period (62 weeks). Swimming is an exemplar sport to test this model considering the high training volumes completed by swimmers (17.3

± 5.3 h/wk in youth swimmers and 26.8 ± 4.8 h/wk in adult swimmers; Feijen et al., 2020), and of note, the early morning training sessions that can prevent the recommended sleeping hours being obtained by swimmers (Sargent et al., 2014).

The pathology of health problems is too complex for a reductionist approach whereby variables identified as risk factors (e.g., training load, sleep, and stress) are quantified in isolation rather than as an interactive multifactorial pattern (Bittencourt et al., 2016). Therefore, we applied a holistic approach to both our data collection method and our analyses by using the AMQ (which measures many factors) and pattern recognition analyses. This analysis (see also Gullich et al. 2019, Jones et al., 2019; Jones et al., 2018) allows for the examination of many complex interactions between variables to ascertain which combination determines a certain outcome (Hastie, 2009; Duda et al., 2007) and so is ideally suited to studies of athlete availability. Further, pattern recognition analyses are ideal to use in situations where the sample size is determined by resource constraints (Lakens, 2021). To the best of our knowledge, no studies have combined such detailed multi-disciplinary approaches to athlete monitoring and cutting-edge analyses to determine the precursors of injury and illness, and thus, the inability of an athlete to complete their training. Therefore, the broad aim of our research was to identify what combination of variables best discriminated between the training availability (relating to health) of a cohort of developing elite swimmers. We hypothesised that a combination of variables from the AMQ (training volumes, injury and illness, sleep, wellbeing, and stress) would be able to accurately distinguish between swimmers depending on the grouping selection criteria. More specifically, we expected those swimmers who were more available to show higher levels of wellbeing, sleep (duration and quality) and lower levels of stress.

3.3 Method

3.31 Participants

The first author and members of the UK Sport/English Institute of Sport approached podium potential swimmers from Swim England about their involvement in the study in July 2019 Fifteen performance squad swimmers (hereafter *swimmers; 19.2 ± 1.7 years old; 9 females, 6 male*) consented to participate. All swimmers were part of a UK sport funded national governing body programme.

3.32 Measures

The Athlete Monitoring Questionnaire (AMQ; see Appendix 2.1 and Chapter 2) is a weekly application tool used to monitor training, sleep, wellbeing, stress, and health. With 23 questions, the AMQ takes approximately 5 minutes to complete. The questions are either exact or slightly modified versions of existing validated monitoring measures. Where items required modification, it was usually about the period (e.g., changing from two weeks to one week) thus, the content of the original item remained the same. We selected questions from validated measures (e.g., Pittsburgh Sleep Quality Index; Buysse et al., 1989) based on criteria of relevance (Horvath & Röthlin, 2018). Initial work (see Chapter 2) supports the discriminant validity of the AMQ by identifying differences in the training, sleep, wellbeing, stress, and health between developing elite and NF athletes.

3.33 Procedures

The study received institutional ethics approval from Bangor University (P10-18/19) on 18th December 2018. Participants completed the AMQ for 62 weeks from November 2019 to January 2021 using a commercially available software system (Qualtrics, 2020). Each participant received an individualised link to the questionnaire weekly via email and/or text. To ensure the correct completion of the AMQ, researchers supervised participants during the first week of data collection according to research recommendation (Boynton, 2004). A 48-h completion window prohibited data from one-week altering responses from another. Non-responders received a reminder after 24 and 48 hours. The utility of the data collected from this measure is limited by athlete adherence thus, by best practice recommendations (Saw et al., 2016) we included various tools (e.g., athlete and coach feedback) to aid adherence. Thus, once the completion window had closed, the research team downloaded the data and generated a weekly feedback document. Swimmers received a weekly longitudinal rolling report via email detailing their responses over the previous 12 weeks. This report contained a series of graphs showing individuals training volumes, sleep, and wellbeing data from week to week. If the athlete consented, nominated coaches and support staff of the pathway swimmers had the option to receive their respective athlete's feedback. The head coach and lead support staff received a simplified group summary of their squad so that health problems or 'red flags[2]' such as injury, illness, or low wellbeing (relative to that individual) could be appropriately addressed.

3.34 Statistical analyses

We utilised pattern recognition analyses to identify the most important combination of discriminatory variables for athlete availability. Pattern recognition was originally developed in bioinformatics as a way of classifying objects depending on the features, they possess (Hastie, 2009). In doing so, users can analyse the multiple and complex interactions of large datasets, thereby overcoming limitations of linear analyses that traditionally assess the sum of multiple 'main effects' (Jones et al., 2018). It is commonly used to analyse short and wide datasets, that is, the datasets that contain more variables than participants, so was appropriate for the current dataset (Güllich et al., 2019; Jones et al., 2018). It is important to note that our

[2] For example, a 2 SD reduction in swimming km or training hours relative to that swimmer, a 2 SD drop in wellbeing or a rise in stress relative to that swimmer, reporting poor quality sleep or reporting a health problem before a competition or training camp.

sample size was governed by external constraints (i.e., only 16 people in this performance squad).

3.341 Grouping

Pattern recognition requires that data be "split" into two groups so that the analysis can determine what combination of variables best explains the differences between these groups. To examine availability, we chose two different variables on which to group participants and ran separate analyses on each grouping variable. We termed the first method "availability (training modification)" and defined this as the availability to participate in training without any modification to training. Hereafter, swimmers available without training modifications at least 90% of the time are known as *'≥90% available without training modifications*', and swimmers available without training modifications less than 90% of the time are known as *'<90% available without training modifications'.* We termed our second method "availability (health problems)" and defined it as the availability of the athlete to participate in training without any health problems. Hereafter, swimmers available without health problems at least 90% of the time are known as *'≥90% available without health problems'*, and swimmers available without health problems less than 90% of the time are known as '*<90% available without health problems'*. The demographics for the swimmers and the grouping variables are presented in Table 3.1.

To allocate swimmers according to the grouping variables, we used part of the AMQ (see Appendix 2.1, AMQ question 10a). To group swimmers for variable 1, those that responded with 'full participation without health problems' at least 90% of the time were put into the *'≥90% available without health problems'* group whilst those who selected this response less than 90% were put in the *'<90% available without health problems'* group. To group swimmers according to grouping variable 2, those that responded with either 'full participation without health problems' or 'full participation, but with injury/illness' at least

90% of the time were put into the *'≥90% available without modifications'* group whilst those who selected either response less than 90% were put in the *'<90% available without modifications'* group. We averaged swimmers' weekly responses throughout data collection (see appendix 3.2 for the full data set). Using these evidence-based thresholds meant that we could not guarantee an equal number of participants in each group. Unequal group sizes are a common occurrence in many applied investigations where sample sizes are limited (Seiffert et al., 2008). We discuss how we dealt with the unequal sample sizes later in this chapter.

Table 3.1 ***Demographics of the swimmers and the availability grouping variables***

	Availability (health problems)		**Availability (modification)**	
	≥90% available without health problems N=5	**<90% available without health problems N=10**	**≥90% available without modifications N=10**	**<90% available without modifications N=5**
Male (%)	4 (80%)	2 (20%)	4 (40%)	2 (40%)
Female (%)	1 (20%)	8 (80%)	6 (60%)	3 (60%)
Age (SD) (years)	19.0 (1.4)	19.3 (1.9)	18.8 (1.4)	20.0 (2.2)

3.35 Data sorting

Once we selected our grouping variables, we sorted and recoded the athlete monitoring (AMQ) data using R software (R Core Team, 2020). We excluded data from the first two weeks of the study by previous recommendations (Clarsen et al., 2013). To remove missing values where swimmers did not complete the weekly AMQ, we averaged the weekly data over a tri-monthly period thus, creating five different time points (T1, November 2019 – February 2020; T2, February 2020– May 2020; T3, May 2020 – August 2020; T4, August 2020 – November 2020; T5, November 2020 – January 2021). The average weekly completion rate for the AMQ was 70% (±26%). This process resulted in 152 variables being available for analysis. The 152 variables presented in the results section should be interpreted as an average weekly score within the given time point as opposed to a tri-monthly average (see appendix 3.2).

3.36 Pattern recognition analysis

The distribution of data is not an issue in Pattern Recognition analyses as this form of analysis does not make any assumptions about how the data are distributed (Anderson, 2020). Pattern recognition analysis involves two stages: feature selection and classification (Güllich et al., 2019; Jones et al., 2019). As previously mentioned, our groups for each grouping variable were unequal. Imbalanced data sets can lead to misclassification or overfitting of data, both of which produce models with no real-world value (Seiffert et al., 2008). Whilst imbalanced sample sizes are not ideal, it is a well-recognised challenge within machine learning (Das et al., 2013). We recruited 94% of the available participants in the eligible sample; thus, further data collection was limited by available resources.

Before feature selection, we normalised data (i.e., maximum, and minimum values for each variable were represented as a 1 and 0, respectively). We then used three machine-learning algorithms in the feature selection process to filter a large data set to identify features (i.e., variables) which have the most predictive power in discriminating between the two groups (see also Güllich et al., 2019; Jones et al., 2019). Based on recommendations, we carried forward the top 40th percentile of variables that featured across all three algorithms in total to the classification stage (Anderson, 2020). Whilst the outcome of the pattern recognition suggests a combination of variables, some variables may have more of an ‘impact’ on the classification than others. For example, “Level 1” variables feature in all four algorithms, “Level 2” variables feature in three of the four algorithms and “Level 3” variables feature in two of the four algorithms. As part of the results, we discuss the impact of each variable concerning the number of times it featured at the feature selection stage.

We utilised three different classification algorithms, including the Naïve Bayes (John & Langley, 1995), Support Vector Machine (SMO; Platt, 1999) and K-nearest neighbours (Aha et al., 1991). Each of these algorithms works differently to learn to select features and classify which groups the swimmers belong to accordingly. The more agreement in the feature selection from these classification algorithms, the more confidence one can place in the results (Güllich et al., 2019). Due to unequal sample sizes, it is inappropriate to measure the performance of a pattern using the overall classification accuracy (Seiffert et al., 2008). Thus, we used Receiver Operating Characteristic (ROC) curves to evaluate the performance of patterns within this study. The area under the ROC curve (AUC) summarises the performance of a classifier over all possible thresholds and is generated by plotting the true positive rate (e.g., predicted 1 and is 1) against the false positive rate (e.g., predicted 1 but 0). ROC curves illustrate the specificity and sensitivity of a classifier. Specificity refers to the ability to correctly exclude swimmers from a group whereas sensitivity refers to the ability to correctly classify swimmers that are meant to be in each group. The AUC value considers both the specificity and the sensitivity of a classifier. The AUC value lies between 0.5 and 1 where 0.5 indicates no discrimination (i.e., 50% accuracy so no better than chance) whilst >0.9 indicates outstanding discrimination (Hosmer et al., 2013; Rice & Harris, 2005).

Following best practice guidelines for small sample sizes (see Anderson, 2020), we performed the classification process iteratively using a 10-fold validation procedure and a leave one out cross-validation procedure. This procedure uses a small subset of training data to estimate the skill of the model on unseen data. We took both these approaches to minimise overfitting the findings to the data, which helped to preserve the generalisability of the resulting model. The resulting classification rate following this process (i.e., the number of swimmers correctly classified versus the total sample size) is therefore an average score for all the iterations.

3.4 Results

3.41 Time frame (COVID-19)

Data collection spanned from November 2019 to January 2021 and should be reflective of a full training and competition season for an elite swimmer. Coronavirus disease 2019 (COVID-19), a respiratory disease, caused a worldwide pandemic from December 2019 onwards. On the 23rd of March 2020, the UK went into its first 'lockdown' whereby citizens were instructed to 'stay at home' until further notice to prevent the spread of the disease. The government lifted the restrictions of Lockdown 1 in early June 2020 allowing swimmers to return to their pool and gym training environments. Due to a continuous rise in COVID-19 infection rates, England was placed under further lockdown restrictions throughout November 2020, and again from late December 2020 until 29th March 2021. Figure 3.1 depicts the temporal progression of the measured AMQ variables such as pool access, training volumes and training hours, health problem prevalence, stress, wellbeing, and sleep whilst Figure 3.2 highlights data collection and lockdown periods. We present these data in Figure 3.1 to demonstrate how training-related variables (did not) change across time. Indeed, T1 (November 2019 – February 2020) reflects a normal period of training (as it occurred pre-lockdown), with T2 (February 2020 – May 2020) and T3 (May 2020 – August 2020) occurring during the first lockdown period. T4 (August 2020 – November 2020) and T5 (November 2020 – January 2020) reflect when restrictions eased enabling swimmers to train normally. The data from T4 and T5 are more representative of the data from the 'normal' training completed in T1. For example, swimmers completed an average weekly swimming distance of 41km in T1 and 35km in both T4 and T5 (Figure 3.2). Thus, whilst T2 and T3 were affected by COVID-19 due to the initial lockdown restrictions, T4 and T5 are more reflective of a typical training period for these swimmers. A one-way ANOVA revealed that there was no statistically significant difference between T1 and T4/T5 in the swimming distances completed ($p = 0.122$), stress ($p = 0.736$), wellbeing ($p = 0.942$) and sleep on rest days ($p = 0.637$). A significant difference was found between T1 and T4 in the sum of swimmers' training and competition hours ($p = 0.008$) but not between T1 and T5 ($p = 0.062$). Further, a significant difference was found between T1 and T5 in the quantity of sleep on training days ($p = 0.008$) but not between T1 and T4 ($p = 0.065$). Therefore, a reader can have confidence in the generalisability of these findings as opposed to our findings being solely a result of the pandemic and lockdown.

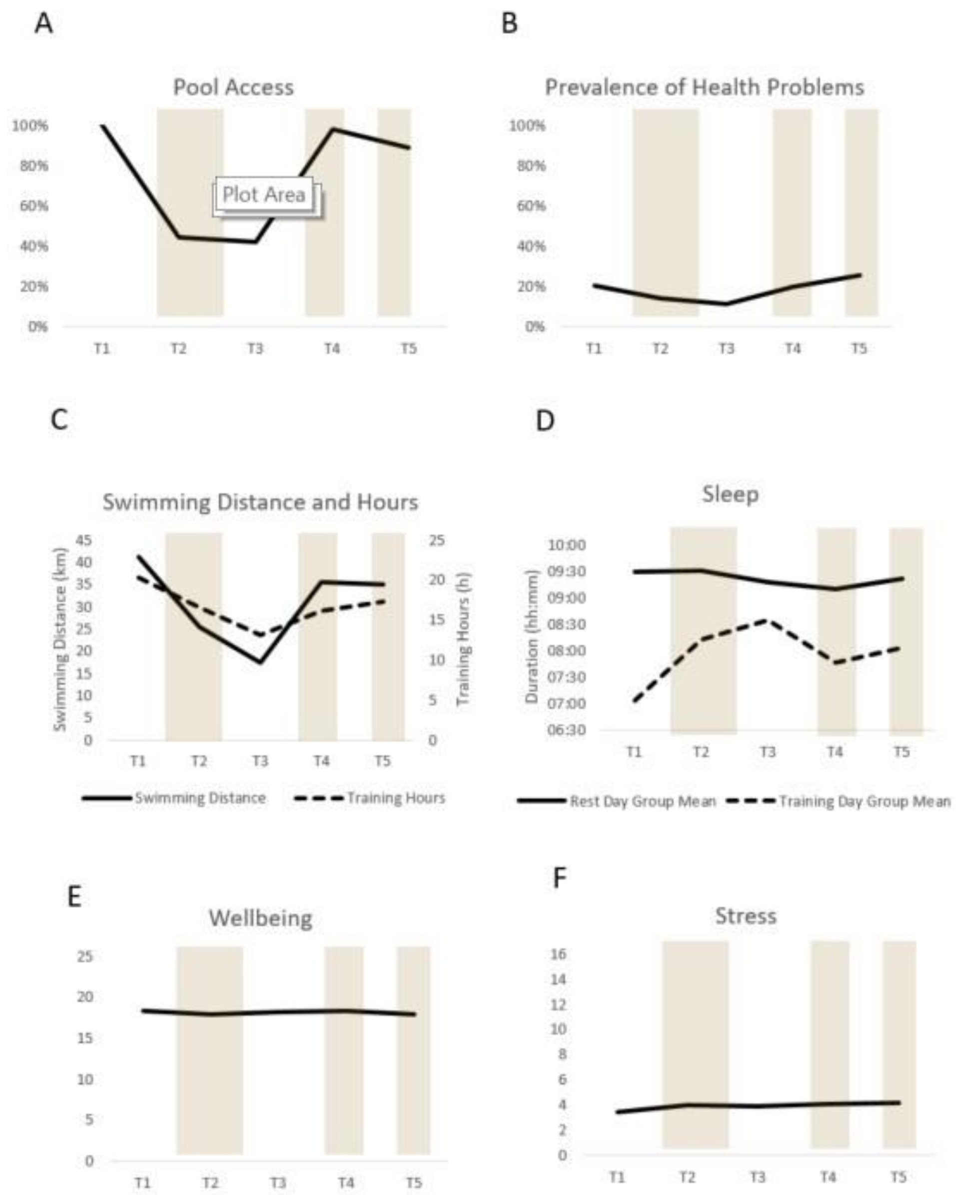

Figure 3.1 *The temporal progression of the measured AMQ variables. Note. The gold area represents COVID-19 lockdown periods.*

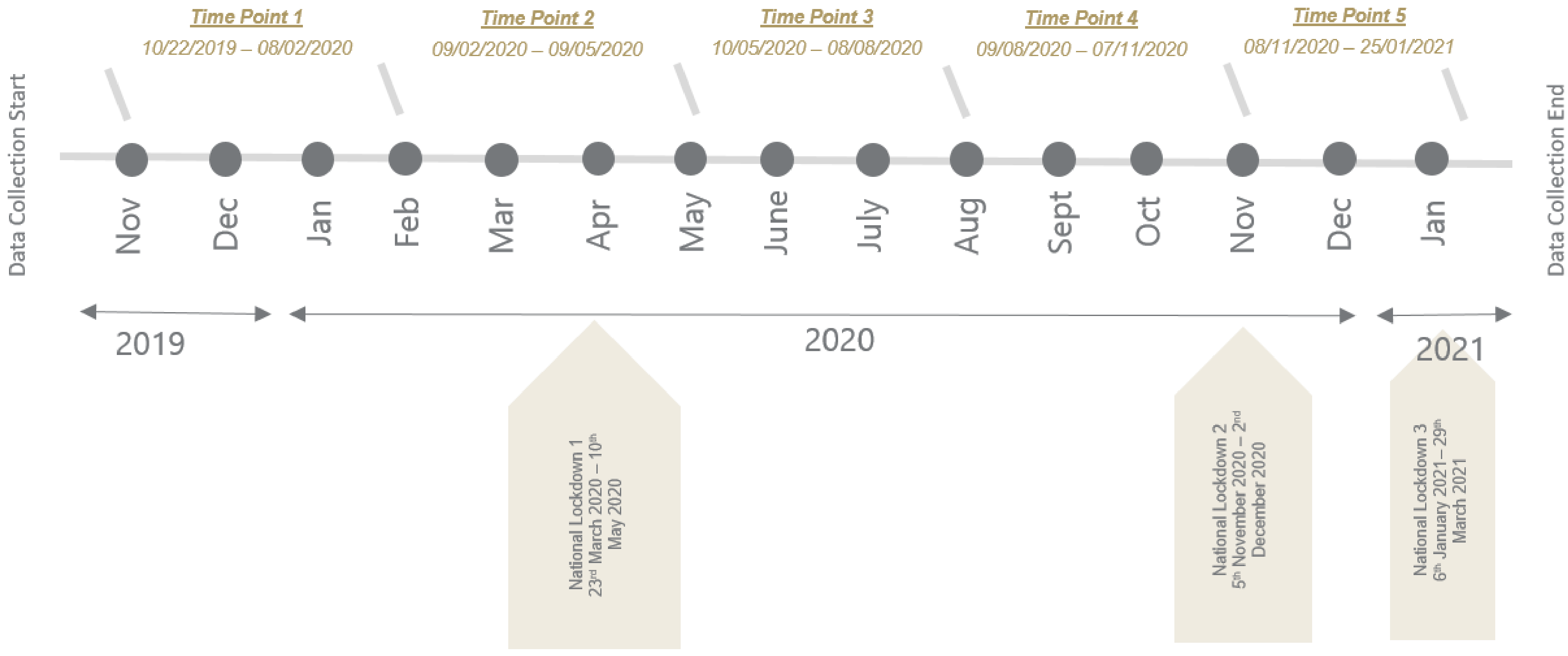

Figure 3.2. *Visualisation of the time points and COVID-19 lockdown periods.*

3.42 Availability (health problems)

From the subset of 152 features (all features are listed in appendix 3.2), the pattern recognition process presented a model of 10 features that were best able to distinguish between those who were available to train without health problems more than or less than 90% of the time. The AUC of all classifiers (0.97, see Table 3.2) suggests that this model has an outstanding ability to discriminate between the two groups. Further, 97% of those not available to train without health problems were correctly classified (specificity) and 93% of those who were available to train without health problems were correctly classified (sensitivity).

The analysis revealed that, across the data collection period, compared to those swimmers who were available less than 90% of the time, swimmers who were available to train above 90% of the time without health problems reported greater average weekly swimming distances and volumes of ‘other training hours’, and reported higher levels of effort (see Figure 3.3 and Table 3.3). Health problems that were experienced were of lower severity and resulted in fewer missed days of training. Furthermore, the more available swimmers reported fewer sleep disturbances and less sleep latency. The features in this model were grouped into three levels of importance based upon their appearance in all four (Level 1), any three (Level 2) or any two (Level 3) feature selection algorithms, respectively. As Table 3.2 shows, sleep issues were identified as predominantly Level 1, which underscores the influence of sleep in discriminating between the groups. At a wider level, it is noteworthy that all but one of the variables in this pattern came from T1, T4 and T5, periods that were largely unaffected by COVID-19. Therefore, we can be more confident that these discriminating variables were not a result of COVID-19 nor due to a singular period. Taken together these findings suggest that the important variables relating to health problems and availability are from largely “normal” periods of training.

Table 3.2. ***Summary statistics for all four-classification algorithms for Availability (Health Problem)***

Classifier	AUC	Accuracy	Sensitivity	Specificity
Naïve Bayes	1	93.3%	0.8	1
Support Vector Machine (SMO)	0.95	93.3%	1	0.90
K-Nearest Neighbour	0.95	93.3%	1	0.90
All Classifiers	0.97	93.3%	0.93	0.93

Note. Accuracy = Correctly classified observations / total number of observations. Sensitivity = 1 – false positive rate. Specificity = 1 – false negative rate. AUC = Area under ROC curve. ROC = Receiver operating characteristic.

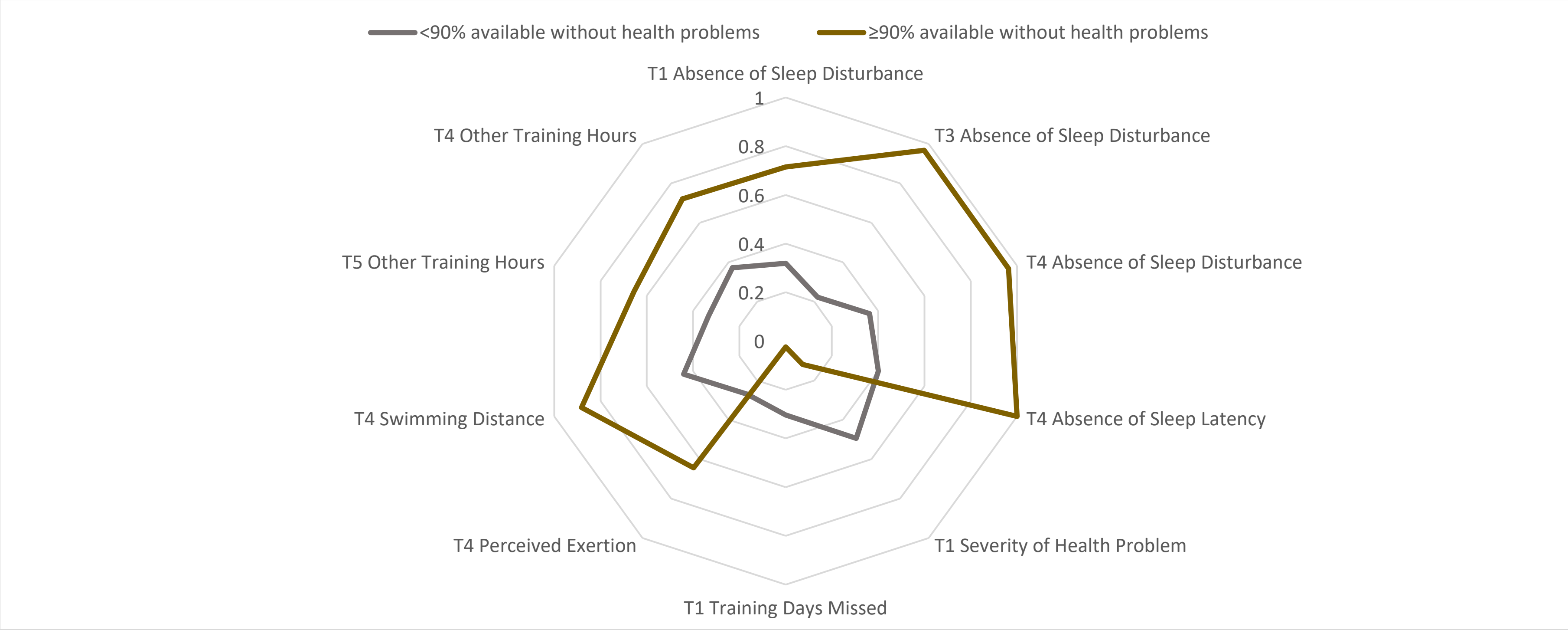

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Figure 3.3

Availability (health problems) Model discriminating between swimmers that were available to train without health problems more than (gold line) or less than (grey line) 90% of the time Note. Data points reflect the normalised mean values for each group (this transformation allows all variables to be displayed on the same scale).

Table 3.3 ***Table of means for variables identified within the Availability (health problems) model***

		<90% available without health problems	**≥90% available without health problems**	**Level**
Training	T4 Swimming Distance (km)	27	47	1
	T4 Perceived Exertion (1-10)	5	6	3
	T4 Other Training Hours	3 hours, 5 minutes	4 hours, 34 minutes	3
	T5 Other Training Hours	3 hours, 32 minutes	5 hours, 15 minutes	3
Health	T1 Severity Score (0-100)	45.4	10.9	2
	T1 Training Days Missed	0.29	0.02	3
Sleep	T4 Absence of Sleep Latency (%)	40	100	1
	T3 Absence of Sleep Disturbance (%)	22	97	1
	T4 Absence of Sleep Disturbance (%)	36	96	1
	T1 Absence of Sleep Disturbance (%)	32	71	3

3.43 Availability (modification)

From a subset of 152 features, the pattern recognition process determined a model of 15 features that distinguished between those who were available to train without modifications due to health problems more or less than 90% of the time (Table 3.4). The overall AUC (0.89) was very good with a high sensitivity parameter. Further, 67% of those not available to train without modifications due to health problems were correctly classified (specificity) and 100% of those who were available to train without modifications due to health problems were correctly classified (sensitivity).

More specifically, the pattern revealed that swimmers who were more available to train without modifications completed a greater volume of other training hours (e.g., land-based training and gym), perceived themselves to be more ready to train, was more motivated and perceived their training required greater effort (see Figure 3.4 and Table 3.5). They reported greater levels of wellbeing and lower levels of stress. Regarding their sleep, the more available swimmers reported less disturbance (i.e., did not wake up at night) and less latency (could fall asleep within 30 minutes of going to sleep). It is noteworthy that in this pattern most discriminating factors came from T2 and T3 (during the lockdown, Figure 3.4), with issues around sleep quality (latency and disturbance) being the strongest discriminator (Level 1, Figure 3.4). The timing of these discriminatory variables is important, as swimmers did not have to negotiate early morning or late-night training alongside work, school, or university commitments because of government-enforced lockdown restrictions.

Table 3.4. ***Summary statistics for all four-classification algorithms for the Availability (modification) grouping***

Classifier	AUC	Accuracy	Sensitivity	Specificity
Naïve Bayes	0.98	86.7%	1	0.6
Support Vector Machine (SMO)	0.90	93.3%	1	0.8
K-Nearest Neighbour	0.80	86.7%	1	0.6
All Classifiers	0.89	99.9%	1	0.67

Note. *Accuracy = Correctly classified observations / total number of observations. Sensitivity = 1 – false positive rate. Specificity = 1 – false negative rate. AUC = Area under ROC curve. ROC = Receiver operating characteristic.*

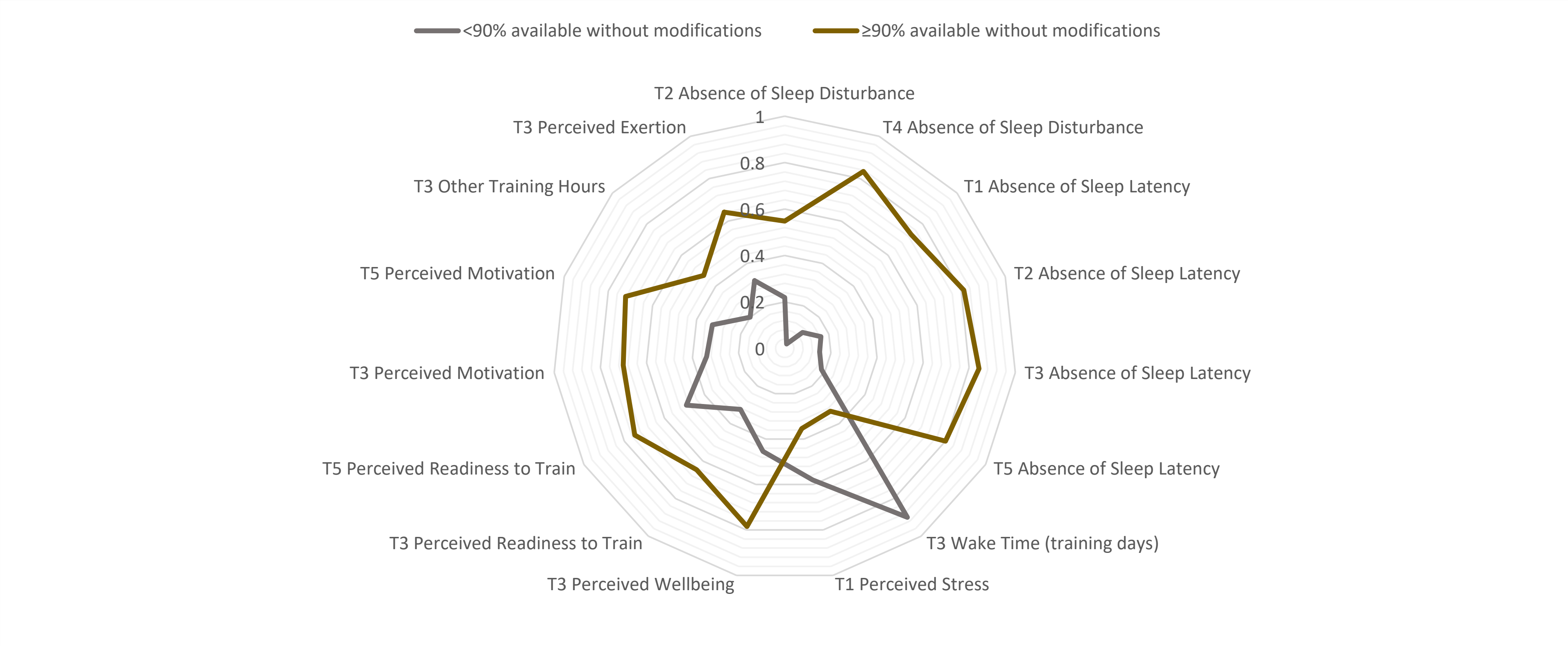

Figure 3.4

Availability (modifications) Model discriminating between swimmers that were available to train without modifications due to health problems more than (gold line) or less than (grey line) 90% of the time. Note. Data points reflect the normalised mean values for each group. This transformation allows all variables to be displayed on the same scale.

Table 3.5 ***Tables of means for variables identified within the Availability (modifications) model.***

		<90% available without modifications	**≥90% available without modifications**	**Level**
Training	T3 Perceived Readiness to Train (0-6)	3.2	4.1	3
	T5 Perceived Readiness to Train (0-6)	3.3	3.9	3
	T3 Perceived Exertion (1-10)	4.3	5.4	3
	T3 Other Training Hours	4 hours, 51 minutes	8 hours, 21 minutes	3
	T3 Perceived Motivation (1-10)	3.0	4.1	1
	T5 Perceived Motivation (1-10)	3.7	4.2	3
Health	T1 Perceived Stress (0-16)	4.6	2.9	2
	T3 Perceived Wellbeing (0-25)	15.7	19.4	3
Sleep	T1 Absence of Sleep Disturbance (%)	32	71	3
	T2 Absence of Sleep Disturbance (%)	22	55	3
	T4 Absence of Sleep Disturbance (%)	2	83	1
	T1 Absence of Sleep Latency (%)	10	73	1
	T2 Absence of Sleep Latency (%)	16	81	1
	T3 Absence of Sleep Latency (%)	15	84	1
	T5 Absence of Sleep Latency (%)	18	80	1

3.5 Discussion

This study aimed to identify the combination of variables that best discriminated between the ability of developing elite swimmers to participate in training without health problems or modifications to training. By using pattern recognition, we were able to apply a holistic approach to analysing the complex interactions of multiple variables associated with a developing elite athlete's availability. From 152 variables, a select few variables were identified as discriminators between athlete availability. In the following sections, we cover each pattern in detail, before exploring the more general implications of these findings and offering recommendations for practitioners and considerations for future research.

3.51 Grouping

We chose two different ways of examining availability to ensure that any findings were generalisable beyond a single method and were not simply an artefact of a grouping variable. We selected these criteria for several reasons. It is widely accepted that to get stronger, fitter, quicker, and more skilful, swimmers need to be available to complete their prescribed training without modification (Raysmith & Drew, 2016). However, injury and illness are an inherent risk of the elite lifestyle and thus, there will be times where modifications to training are required (Soligard et al., 2016). The proportion of these modifications, however, should be minimal. Raysmith and Drew (2016) found that elite adult track and field athletes needed to complete at least 80% of their planned training without modification to achieve their performance goals. We combined this empirical evidence with expert opinion and outlier evidence from several key individuals in British Swimming, who suggested that an athlete should be fully available to participate (without modification) in training and competition at least 90% of the time to achieve performance progression in their pathway. The two grouping approaches both assess availability but from different perspectives; the first acknowledges that swimmers may have an underlying health problem, but this has no effect on training, whilst the second focuses on a swimmers' ability to train in the absence of health problems. Using two related yet different grouping variables allows for a more detailed understanding of the determinants of athlete availability regarding performance (availability without modifications) and holistic wellbeing (availability without health problems).

3.52 Pattern 1: availability without health problems

In Pattern 1 we examined the factors that discriminated between swimmers who were available to participate in training without health problems more than or less than 90% of the time. The pattern suggested that more available swimmers experienced health problems of lower severity that resulted in fewer missed training days, which enabled these swimmers to complete higher volumes of training at higher perceived exertions across the data collection period. Lower health problem prevalence or burden might provide an athlete with an opportunity to train more but the quality of the training session cannot be assured. Therefore, these results are not simply a reflection of the way the grouping variable was calculated.

Swimmers in the '≥90% available without health problems' group reported better sleep quality as indicated by a lower prevalence of sleep disturbance across T1 and T3, and lower disturbance and shorter latency across T4. Sleep has important physiological and psychological restorative effects that are essential for athletic recovery (Venter, 2012; Walsh et al., 2020; Watson, 2017). Sleep is fundamental for athlete recovery (Halson, 2008). In particular, the release of growth hormone (GH), useful in restoring metabolic processes, is largely dependent upon sleep (Sassin et al., 1969). Approximately two-thirds of the daily supply of GH is released during non-rapid eye movement (NREM) sleep (i.e., deep sleep; Obal & Krueger, 2004). Thus, for peak physiological growth and repair to occur, an individual is required to enter NREM sleep multiple times (Leproult & van Cauter, 2009; Venter, 2012). Previous studies in sleep-deprived healthy males (Ritsche et al., 2014) and war veterans with post-traumatic stress disorder (van Liempt et al., 2011) found that GH secretion was compromised by sleep fragmentation whereby NREM sleep was disrupted. An athlete experiencing continual sleep disruption or failing to obtain the recommended amount of sleep would limit NREM sleep and therefore the release of nocturnal GH (Ritsche et al., 2014; van Liempt et al., 2011). Without the appropriate restoration, an athlete's ability to adapt to the training stimulus diminishes and thus, may hinder rather than benefit athletic performance (Halson, 2008).

In addition to the specific variables that arose from the analyses, it was noteworthy that the variables for Pattern 1 predominantly featured T1 and T4 variables with only single variables from T3 and T5. T1 and T4 are reflective of training periods without lockdown restrictions and pool closures, thus suggesting that the training, sleep, and health of developing elite swimmers in these more "normal" periods of training is most relevant to being able to distinguish between swimmers who were able to train with and without health problems as opposed to the time points affected by COVID-19.

3.53 Pattern 2: availability without training modifications

Pattern 2 reflects variables that discriminated between swimmers who were available to participate in training without modifications due to health problems more or less than 90% of the time. Swimmers with fewer modifications to training reported that they were more motivated and ready to train thus, were able to train harder and for longer; they reported higher wellbeing and lower stress and were able to fall asleep quicker with fewer sleep disturbances.

Stress or worry has been identified as a primary cause of sleep disturbance and latency (Erlacher et al., 2011; Juliff et al., 2015; Lund et al., 2010). Without these states of hyper-arousal (i.e., stress; Gupta et al., 2017) an athlete is more likely to experience less sleep disturbance and sleep latency indicating better sleep quality. Sleep quality, either absence of disturbance or latency, appeared across all classifiers (Level 1) and all-time points, indicating the importance of sleep in being able to train without modifications. Better quality sleep (i.e., undisturbed sleep) is associated with improved psychological health and wellbeing (Fullagar et al., 2015), and is essential for optimum recovery (Horgan et al., 2021). Thus, it is notable that swimmers who reported less sleep disturbance and lower sleep latency also reported lower levels of stress, higher levels of wellbeing and perceived themselves as more motivated and ready to train. Consequently, the data suggest that the improved psychological health and restorative effect of sleep enabled swimmers to complete high volumes of training at higher perceived exertions throughout extreme difficulties (namely the national lockdown during T3). That said, our current analytical approach could not infer the direction of the causality between sleep and the other variables. Thus, the lower levels of stress, higher levels of wellbeing and motivation perceived by the athletes may have resulted in better quality sleep (less sleep disturbance and lower sleep latency).

The results of this study showed that swimmers who were more available to complete training with no modifications completed more training hours and swimming kilometres at higher perceived efforts, were more motivated to train and perceived themselves as more ready to train (Kellmann et al., 2018). Being highly motivated and ‘ready to train’ speaks to a positive mindset (Hamlin et al., 2019), which may well be reflected in the higher levels of wellbeing and lower levels of stress (Reardon et al., 2019) reported by swimmers in the ≥90% available without modifications group. The high prevalence of psychological variables in this pattern suggests that mindset may play a greater role in the ability to complete the training without modification in comparison to the ability to train without health problems.

Considering this pattern more broadly, it is apparent that most variables came out during T2 and T3 (i.e., throughout lockdown, see Figure 3.2). T2 and T3 are reflective of an extremely disrupted training period for these swimmers whereby they only had pool access 44% and 42% of the time due to COVID-19 (T2 and T3 respectively). The ability to positively cope with adversity has been identified as vital for optimal sports performance (Fletcher & Sarkar, 2012; Hardy et al., 2017). With the temporal nature of the pattern in mind, the high prevalence of positive psychological variables (e.g., high wellbeing, low stress, high motivation) suggests that swimmers in the '≥90% available without modifications' group may have a more adaptive mindset when faced with adversity. This finding is consistent with the view that being able to positively cope with adversity can have a direct impact on training behaviours (Woodman et al., 2010) and health (Caine et al., 2016; Williams & Andersen, 2008). It may be worthwhile to explore this proposed mechanism explicitly in further research by examining the direct impact of wellbeing on the performance and health of developing elite swimmers.

3.54 General overview and implications

Patterns 1 and 2 present the most important combination of variables that best determine health problem prevalence and the ability of an athlete to participate in full training without any modifications, respectively. Not all variables were selected in the models; however, this does not mean that they are not important. These analyses identify discriminating variables so it is important to note that other variables may also be of importance, but they may be *common* between both groups of swimmers. That is, all swimmers need the variable to be available to train and compete without health problems (e.g., obtain the recommended quantity of sleep at night). What these patterns show is that a different combination of factors underpins these different, yet related, measures of availability. This point has important theoretical implications and implications for practitioners . At a theoretical level, it is evident that different aspects of availability are underpinned by different factors. Thus, when one is trying to understand the determinants of athlete availability, it is important to consider how availability is conceptualised and measured, as the conceptualisation will likely have some influence on the most important factors that come out as discriminating. At an applied level, depending on what the organisation, athlete or practitioner feels is most important regarding availability (i.e., absence of health problems or absence of training modifications) they may want to focus their efforts on factors that appear most relevant to meet their availability criterion**.** The positive implication for practitioners is that many of the key discriminators in both patterns are modifiable.

Sleep appears to be relevant to both aspects of availability. To experience fewer health problems, obtaining good sleep quality appears to be vital as this may help recovery from the higher training loads completed by elite developing swimmers. It is worth noting that the subjective rating of sleep quality (a 4-point Likert scale asking swimmers to rate their sleep from very bad to very good) does not come out as a discriminator. However, the absence of sleep disturbance and sleep latency appeared in both patterns. As suggested by (Knufinke et al., 2018), sleep latency and disturbance may be a better indicator of sleep quality rather than a singular subjective question. Accordingly, practitioners may look to implement strategies that address latency and disturbance to improve sleep quality. For example, swimmers should be encouraged to adopt good sleep hygiene behaviours such as avoiding caffeine after 2 pm, maintaining regular bedtime and wake time routines and rituals, sleep disorder identification, and avoiding blue light from screens at least 2 h before bed (Simpson et al., 2017).

To participate in training without modification, the ability to adapt to difficult situations appears important. The higher levels of wellbeing, lower stress and greater motivation of swimmers who can train more likely facilitate a high volume of effortful training. To improve wellbeing and lower stress, sports may consider implementing regular health screening of their swimmers to ensure issues are identified early and at-risk individuals receive the treatment they need (Reardon et al., 2019). Furthermore, coaches, swimmers and stakeholders should be educated with relevant information to create a supportive environment (Reardon et al., 2019). Considering that sleep has a direct influence on the mental well-being of swimmers (Asplund & Chang, 2020), education on good sleep hygiene would be a good place to start. Furthermore, fully educating coaches in using evidence-based coach behaviours that are known to improve health and wellbeing would likely be of substantial benefit (Felton & Jowett, 2017). For example, coaches could be educated in how to help swimmers to satisfy basic psychological as advocated by Self Determination Theory**,** (Ng et al., 2011; Ryan & Deci, 2000) or to consider transformational leader behaviours that inspire, challenge and support swimmersas such approaches are known to positively influence athlete health, wellbeing and performance (Arthur et al., 2012; Hardy et al., 2010).

3.55 Limitations and future directions

It is important to acknowledge that this study is not written to highlight the determinants of health problems but to highlight what combinations of variables may affect a developing swimmers' availability to participate in training without health problems or without the need to modify training. The reliance on self-report measures, as opposed to objective measurements, is a potential limitation of this study. For example, we utilised self-report questions to assess sleep quantity and quality rather than objective markers of sleep such as actigraphy (Leeder at al., 2012). However, while objective measures in principle allow researchers to circumvent some of the challenges of self-report data, in the current study these objective measures were not feasible options due to the logistical challenge of longitudinal data collection (63 weeks), the remote locations of the sample and ensuring data collection was of minimal burden to participants. Further research may extend this work by considering using a combination of self-report, physiological and behavioural markers.

What's more, the AMQ is limited by the exclusion of female-specific factors regarding the menstrual cycle. It is suggested that the menstrual cycle has a detrimental effect on athletic performance, particularly around the early follicular phase (McNulty et all., 2020; Carmichael et al., 2021). Whist the research regarding the exact performance effect is inconclusive due to methodological complexities (Elliot-Sale, 2021), a recent study by Brown et al (2021) demonstrated that females perceive that symptoms associated with their menstrual cycle prevented them from training to their full capacity. Therefore, the menstrual cycle has the potential to detriment athlete availability to train and compete. The selected sample and the advanced data analysis using pattern recognition procedures are strengths of this study. That said, these findings refer to an elite sporting sample and so should not be overly generalised. We were able to recruit 94% of all UK pathway swimmers (15 of a possible 16), yet we acknowledge that the sample size remains small. Collecting more data from lower levels or different sports would have helped to increase the sample size, yet this increase would likely come at a cost to specificity, as we would not have been able to provide such a detailed insight into factors predicting availability in developing elite swimmers. To reduce the effects of the sample size, we implemented multiple algorithms to minimise the potential for overfitting and to maximise confidence and to maximise our confidence in the results (Jain

& Chandrasekaran, 1982). Taking these issues in concert, future research should replicate and extend these findings with a larger sample in different sports to provide a more complete understanding of the factors influencing athlete availability

3.56 Concluding remarks

Our results show the combination of variables that discriminate between the availability of swimmers that are more available to participate in training without health problems or training modifications at least 90% of the time. Although we cannot establish cause and effect, we observed that more available swimmers also reported higher volumes of training, had better health (lower prevalence of health problems, higher wellbeing, and lower psychological stress), and experienced a better quality of night-time sleep (i.e., could fall asleep within 30 minutes and did not wake up at night) than less available swimmers. Such a holistic approach to examining training availability provides researchers and practitioners with key information regarding the most relevant athlete availability variables, allowing swimmers and coaches to make key changes to their approach to training to ensure that swimmers are available to train as often as possible.

Each of the patterns presented in the results includes at least one variable related to training, sleep, and health. These findings support the idea that athlete availability is not determined through unidimensional constructs; rather availability is best understood via a multidimensional approach, which considers (at least) training, sleep and psychological stress and wellbeing.

Chapter 4: The importance of athlete availability, sleep, wellbeing, and health in the context of talent development and progression.

4.1 Foreword

The chapter below is an adapted version of the final executive report, part of which was provided to Swim England and British Swimming on completion of the P2P project. The reader is reminded that this chapter is not written as a traditional scientific chapter and is placed within this thesis to demonstrate the applied nature of the PhD. A requirement of the project was to provide bi-annual, annual, and final executive reports to the sports and funding bodies. As this formed a large part of the work throughout the PhD, we deemed it important to demonstrate how the feedback was provided. The language and structure of this chapter is written as an executive summary report and is presented in three parts. We begin by outlining the project and its aims, followed by an overview of the methods. The results section is split into 1) the descriptive results of the practice and training, health, and psychosocial data, 2) the results of the pattern recognition where all the bio-psycho-social factors are viewed multidimensionally, and 3) a summary of the qualitative interview. Due to the multitude of findings from this study and for the ease of the reader, we discuss the inclusion of these factors and implication of the results within the results section. We build upon these results in the discussion by considering all the factors holistically and providing a series of evidence-based suggestions to enhance the Swim England pathway and development of athletes.

4.2 Introduction

The limited talent identification and development literature in swimming are largely based upon specific unidimensional lines of enquiry, such as early specialisation (Yustres et al., 2019), performance time (Yustres et al., 2019), or anthropometrics (Ackland, 1999). To our knowledge, there have been no longitudinal multidimensional studies investigating the development of national-level athletes.

Pathway 2 Podium (P2P) is a collaborative research project between Bangor University and the EIS Performance Pathways Team, in partnership with a range of sports, and funded by UK Sport and the Economic and Social Research Council (ESRC). P2P is a longitudinal and prospective study of development (or "pathway") athletes. The project attempts to identify bio-psycho-social factors that influence the development of high-level sports performers. Specifically, we examined the complex ways in which different pathway, individual, and coaching factors affect athletes' availability and ability to thrive in the high-performance sports environment. The factors under investigation included demographics (e.g., birth-date, birthplace and schooling), early life experience (e.g., relationship with parents/guardians), practice and training information (e.g., training volumes, developmental sporting history, milestones and achievements in sport, past and current training activities), health (e.g., sleep, wellbeing, stress, injury and illness), psychosocial factors (e.g., personality, skills and behaviours), coach factors (e.g., coach-swimmer relationship, coaching style and support provided), and organisational variables (e.g., the culture of the sporting environment). This empirical study aimed to identify the combination of training and health factors that were important to discriminate between higher potential - high-level athletes who were identified as most likely to progress in the high-performance system – and lower potential athletes – high-level athletes less likely to progress in the high-performance system.

4.3 Method

4.31 Participants

We invited 16 Swim England Performance Squad athletes and 13 of their coaches to participate in the study. All 16 athletes agreed to participate (10 females, 6 males, age 19.3 ± 1.9 years) alongside 11 swimming coaches and the Head of Talent (HOT). All but one swimmer had coaches that participated in the project. The transition of athletes to different clubs meant that four coaches stopped participating (May 2020) and one additional coach joined the project (August 2020) with the other athletes joining coaches who were already participating in the study. Athletes and their coaches were based at Manchester, Sheffield, Leicester, Loughborough, Millfield, Bath, High Wycombe, Derby, Plymouth, Coventry, and Leeds. Two of the 16 athletes were deselected from the programme in December 2020 and one swimmer retired from competing in February 2021. Data for these three athletes are included in the analyses. The remaining 13 athletes retained their place on the Swim England programme. Three additional (female) athletes (age 18 ± 3.5 years) and one coach joined the programme in December 2020 and consented to participate in the study from 10th January 2021. Note that we could not include these athletes in the main pattern recognition analyses due to insufficient data, though we include them where appropriate in the descriptive summaries.

4.32 Measures

As discussed, talent identification and development can be conceptualised as multidisciplinary. We, therefore, wanted to measure multiple constructs associated with athletic talent. This included health, stress, retrospective and prospective practice and training, psychological skills, demographics, early life experiences, career experiences, personality and attitudes to sport, competition, and relationships with other people. Due to the nature of working in applied elite sport, we had to minimise the burden of data collection for the participants. With this in mind, we selected and developed measures that were valid, reliable, and of course, of minimal burden to the participants concerning time commitment. Given the absence of appropriate measures to address the many concepts, there was a need to develop an alternative method that would address the limitations of the participation burden. We present the breakdown of each measure and its development below.

4.321 Athlete Monitoring Questionnaire

We utilised the Athlete Monitoring Questionnaire (AMQ), a weekly measure of training volume, sleep, wellbeing, stress, recovery and injury and illness. The first empirical chapter of this thesis demonstrates the applicability of this measure across athletic levels. The second empirical chapter and executive sports report extend the utility of the AMQ by establishing how each factor measured contributes towards athlete availability.

We designed the AMQ to measure external and internal training load, recovery, sleep, perceived stress, perceived wellbeing, and health problems. Based on our review of these variables, we provide details on how we measured each construct below.

External training load. We measured training volume using weekly training hours and split this into several categories, for example, sport-specific training hours, competition training hours, general training hours (e.g., strength and conditioning), and frequency of competition/races. This approach is relevant to all sport types and provides sufficient detail concerning training and competition volumes completed by athletes.

Internal training load. We decided to modify the timing of the RPE scale whereby participants are asked to provide an overall RPE for a training week. Whilst this does not provide a true reflection of individual sessions. Phibbs et al. (2017) found a moderate correlation between the sRPE after 24 hours and an RPE score provided at the end of the same week. This weekly simplification still indicates the overall weekly effort without being a hindrance to both athlete time and recall ability.

Recovery. We included the Perceived Recovery Scale (PRS; Laurent et al., 2011) in the AMQ. Based upon the RPE scale, the PRS is a single item scale that asks individuals to subjectively rate their perceived level of recovery where 0 = very poorly recovered and 10 = very well recovered. In addition, we also used a measure of readiness to train developed by (Pruscino et al., 2013). The measure asked athletes to rate how often they felt ready to train over the past week on a 6-point Likert scale (5 = “all of the time”, 4 = “most of the time”, 3= “more than half of the time”, 2= “less than half of the time”, 1= “some of the time”, 0= “at no time”). An additional point to both these scales allowed athletes to indicate if they had not trained.

Sleep. We drew from both the ASSQ (Samuels et al., 2016) and PSQI (Buysse et al., 1989) when deciding which items to use to assess sleep. More specifically, we selected three items measuring sleep quality, quantity, and latency from the PSQI alongside two additional items measuring the number of days napping and daytime napping hours from the ASSQ. The items from the PSQI included ratings of sleep quality scored using a 4-point Likert scale where 1 = ‘very good’, 2 = ‘fairly good’, 3 = ‘fairly bad’ and 4 = ‘very bad’. Sleep latency and sleep disturbance were also measured using a 4-point Likert scale where 1 = ‘Not during the past week’, 2 = ‘less than once a week’, 3 = ‘Once or twice a week’ and 4 = ‘three or more times a week’.

Perceived stress. Considering the time burden, we decided to use the validated 4-item version of the Perceived Stress Scale (PSS; Cohen et al., 1983) in the AMQ due to its brevity.

Wellbeing. We used the 5-item World Health Organisation (Topp et al., 2015) wellbeing scale to measure subjective psychological wellbeing.

Injury and illness. Current injury and illness surveillance tools underestimate the impact of injuries and illnesses by assuming that all health problems can be categorised by the loss of training days or require medical attention. Unlike previous injury and illness surveillance methods, the Oslo Sports Trauma Research Centre (OSTRC) health problems questionnaire (Clarsen et al., 2014) looks beyond these. This tool acknowledges that an overuse injury for example may not cause a loss of training days but may require a small modification in training. The OSTRC is fast becoming a popular tool in sports injury and illness surveillance with the provision of data surrounding injury and illness severity, training modifications, participation and performance reductions and symptom experience (Clarsen et al., 2020).. Using the OSTRC questionnaire and instructions, athletes reported health problems and symptoms over the past week as well as the consequences of the experienced health problem on participation/availability, training volume and performance. Supplementary questions provided further detail concerning the nature of the health problems (injury, illness or other), the location and nature (for injury) and symptoms (for illness) experienced. The location, nature and symptom options are based on a recent consensus statement on injury and illness definitions (Timpka et al., 2014). Furthermore, we also recorded the impact of the symptom (i.e., training days missed) and the mode of onset (i.e. single or reoccurrence).

4.322 Practice and training measures.

Athletes and coaches were interviewed at the start of the study and every 3 months thereafter. This interview was designed to find out key demographics, training and competition history and current athlete experience of practice and training design. Details on the content of these interviews are available on request and further discussion can be found in Dunn (2021, PhD Thesis).

4.323 Psychosocial measures.

The first two psychosocial measure used were the Athlete Development Formulation Survey (ADFS) and the Coach Development Formulation Survey (CDFS), questionnaires that focus on life experiences, personality, and training behaviours. The ADFS and CDFS were developed based on a review of previous studies that have investigated the influence of psychosocial factors on expertise development (e.g., Güllich et al., 2019) as well as similar talent development projects conducted in elite rugby (Turner, 2021) and weightlifting (Anderson, 2020). The real utility of the ADFS and CDFS is that they allow a detailed profile to be constructed for each athlete and coach, respectively, as opposed to simply relying on group norms. Details on the validation of this questionnaire and detail surrounding what the ADFS and CDFS measures is available on request and further discussion can be found in Langham-Walsh (2021, PhD Thesis). The third psychosocial questionnaire developed was the Prospective Psychosocial Survey (PPS). The aim of the PPS was to examine swimmer perceptions of coach behaviours alongside coach perceptions of the same behaviours. The PPS includes several classes of behaviours including transformational coach behaviours (the extent to which coaches inspire, challenge and support athletes to reach their full potential (Callow et al., 2009) need supportive coach behaviours (the extent to which coaches are autonomy-supportive, provide structure, and have a genuine interest in their athletes (Ryan & Deci, 1985), coach swimmer relationships (the extent to which there is closeness, commitment, cooperation and complementary behaviours within the relationship (Jowett et al., 2012), social support behaviours (the extent to which coaches provide emotional, informational, tangible, and confidence support (Rees & Hardy, 2000), and effective coaching behaviours (the extent to which coaches used effective questioning, motivational and developmental feedback, individual consideration, goal setting and observation (Wagstaff et al., 2017). Each variable was scored using a Likert scale from 1 (strongly disagree) to 5 (strongly agree). As these variables are considered state-like (and thus are amenable to change over time), the PSS was completed by both athletes and coaches every 6 months throughout the data collection period.

4.3 Data collection

A schematic detailing the annual data collection timeline and the measures taken is provided in Figure 4.1. Data collection took place from October 2019 to April 2021, either in person (club, camp, or competition visits) or via online platforms, phone call or email, with the method of data collection used largely dependent on swimmer/coach availability and their personal preference. Throughout COVID-19 (23rd March 2020 onwards), we completed all data collection remotely).

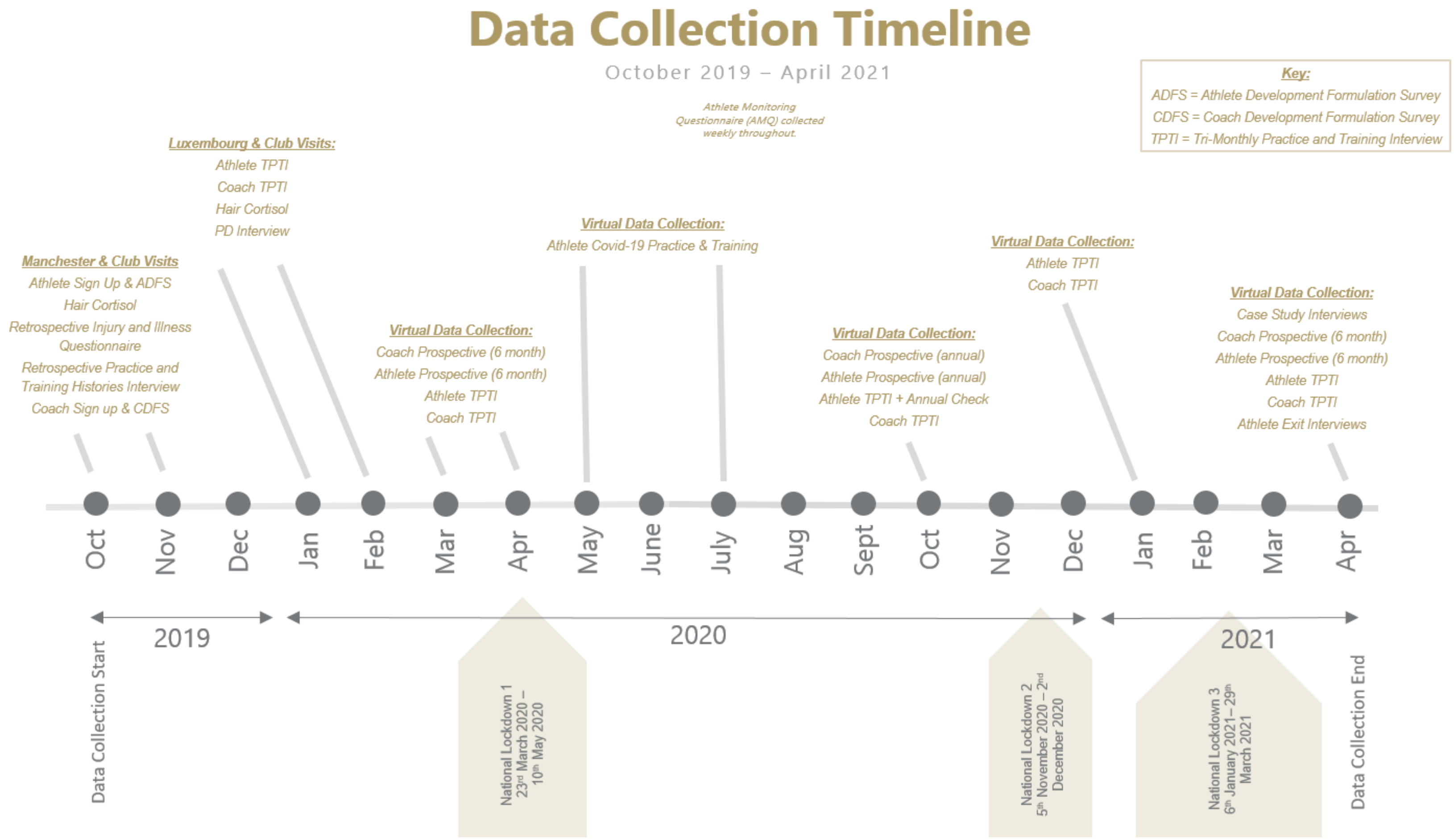

Figure 4.1. *Overview of data collection measures and timeline*

4.31 COVID-19

Coronavirus disease (COVID-19), a respiratory disease, caused a worldwide pandemic when it swept from nation to nation from December 2019 onwards. On the 23rd March 2020, the UK went into its first ‘lockdown’ whereby citizens were instructed to ‘stay at home’ until further notice to prevent the spread of the disease. The government lifted the restrictions of Lockdown 1 in early June 2020, allowing athletes to return to their pool and gym training environments. Due to a continuous rise in COVID-19 infection rates, England was placed under further lockdown restrictions throughout November 2020, and again from late December 2020 until 29th March 2021 (Figure 4.1). Throughout these periods, athletes experienced differing levels of access to swimming pools (Figure 4.2). Except for the lockdown from March to June 2020, pool access was consistent throughout the data collection period.

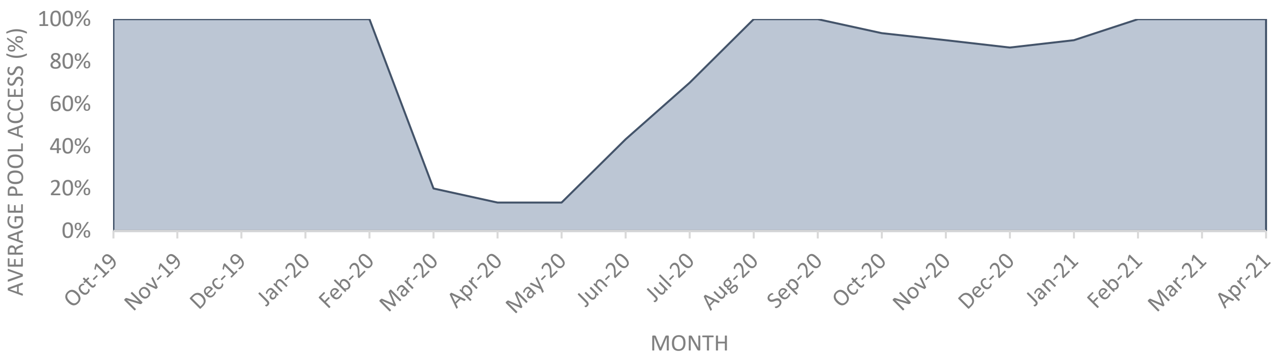

Figure 4.2. *Average swimmer pool access throughout data collection*

4.4 Qualitative data analysis

To gain greater depth to our findings, we supplemented our quantitative data with two qualitative interviews, one swimmer and one Head of Talent (HoT). The aim of the psychosocial life story interview with the athlete was to gain a greater understanding of their development, including whist being part of the Swim England programme. The interview consisted of questions about six main themes: 1) critical developmental experiences; 2) relationship with sport; 3) pressure zone and emotional regulation; 4) personality; 5) relationships with family and coaches; and 6) career turning points. We present a swimmer's perspective by weaving in quotes from this interview within the quantitative results to provide greater richness to our findings. The Head of Talent interview aimed to find out how Swim England approach achievement, wellbeing, innovation, and internal processes about their Performance Squad. Further details of this interview can be sound in Part 3 of the results section.

4.5 Quantitative data analysis

We used a combination of descriptive statistics and state of the art pattern recognition analysis to analyse the data. Descriptive data are presented in the first half of this report whilst the second half focuses on the results of the pattern recognition analyses.

4.6 Hair cortisol

Hair cortisol analysis is fast becoming a well-recognised marker of chronic stress (Abell et al., 2016; Skoluda et al., 2012; Stalder et al., 2017; Steudte-Schmiedgen et al., 2015). In contrast to traditional blood and saliva cortisol, which can be used to assess acute stressors such as training load and psychological stress, hair cortisol is a chronic stress biomarker. Hair cortisol accumulation occurs during the formation of the hair shaft via blood circulation (Heimburge et al., 2019). The cortisol deposited into growing hair is proportional to the quantity of cortisol in circulation at any given point in time (Greff et al., 2019). As hair growth is slow (~1 cm per month; Wennig, 2000), it is a relatively stable stress biomarker. We planned to collect a hair sample every three months throughout the data collection period. Unfortunately, after two collections this was not possible due to COVID-19 restrictions to travel and face-to-face data collection. Consequently, we have been unable to complete the proposed hair cortisol analyses or include hair cortisol within other multiple variable analyses.[3]

4.7 Part 1: Descriptive statistics

This section provides an overview of the data collected, including demographics, practice, and training in the year before joining the Swim England Performance Programme, practice and training between October 2019 and April 2021, psychosocial and training/health data. The following section includes data from the main 16 athletes plus the additional 3 athletes (N = 19, 13 females, 6 males, age 19.8 ± 2.1 years).

4.71 Demographics and prior to joining the pathway

4.712 Relative age effect

Within sport, the relative age effect (RAE) describes an overrepresentation of athletes born early in a calendar year (i.e., Quarter one, or ‘Q1’) and is highly prevalent within youth sport pathways (Jones et al., 2018). This effect is generally shown to dissipate at the senior-elite level. RAE in youth sport is often attributed to physical maturation differences (Cobley

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[3] As part of this PhD, I lead on the exploration of hair cortisol analysis. As part of this process, I worked closely with other PhD researchers at Bangor University to explore of the feasibility of these methods by completing pilot studies in 2018-2019 (details of which can be found in Barwood, 2021, PhD Thesis). However, due to COVID-19 restrictions to travel and face-to-face data collection, we have been unable to complete the proposed hair cortisol analyses or include hair cortisol within other multiple variable analyses.

et al., 2015), where chronologically older athletes are said to be more physically developed than the chronologically younger athletes, providing them with a competitive advantage. This competitive advantage is suggested to begin early in development, where athletes are initially selected (and subsequently remain attached) onto talent pathways based on prioritisation of early success, i.e., physical dominance (Bailey et al., 2010). This process is indicative of the 'survival of the fittest concept, whereby those who demonstrate early physical maturity best fit the criteria of these selection processes (Jones et al., 2018). Such a bias imposes a significant challenge for Q4 athletes wishing to progress along the sport pathway, often resulting in 'de-selection', where the Q4 athletes who are least physically mature drop out of the pathway. This point is important since at the elite level it is often reported that there is a reversal of the RAE with Q4 athletes achieving greater success (Jones et al., 2018). Figure 4.3 indicates that there is a relatively event split between the birth quartiles of the athletes within this study.

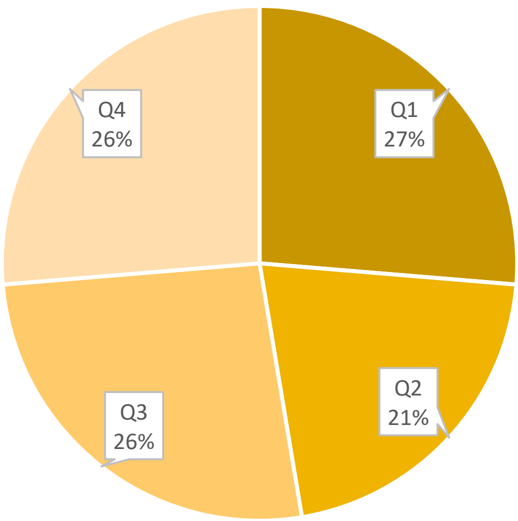

Figure 4.3. Birth quarter proportion (Q1 = Jan-Mar; Q2 = Apr-Jun, Q3 = Jul-Sept; Q4 = Oct-Dec).

4.713 Sibling effect

The family are known to be an important socialization agent for children's sport participation, as well as highly influential on the development process (Fredricks & Eccles, 2005). Siblings have been identified as important correlates of physical activity levels (Duncan et al., 2004), sports participation (Rees et al., 2016), and elite sporting status (Hopwood et al., 2015). The swimmer interview also highlighted the importance of the sibling effect:

"I think there was a bit of competitiveness, definitely from my side, she is the older sister, swimming, and I just wanted to follow her and get better"

Importantly, the proposed mechanisms for this sibling effect (i.e., increased competition, enhanced support, positive role models, training partners and facilitators) and the relationship to elite sporting status is dependent on birth order with elite athletes more likely to be later-born children (Hopwood et al., 2015). Figure 4.4 indicates all but one swimmer had a sibling, and all but four had older siblings. It would be worthwhile trying to understand how one or more siblings having influences athlete development (both positively and negatively), and especially for those who are only children, consider how some of the positive effects might be experienced elsewhere (e.g. through swimming peers / significant others).

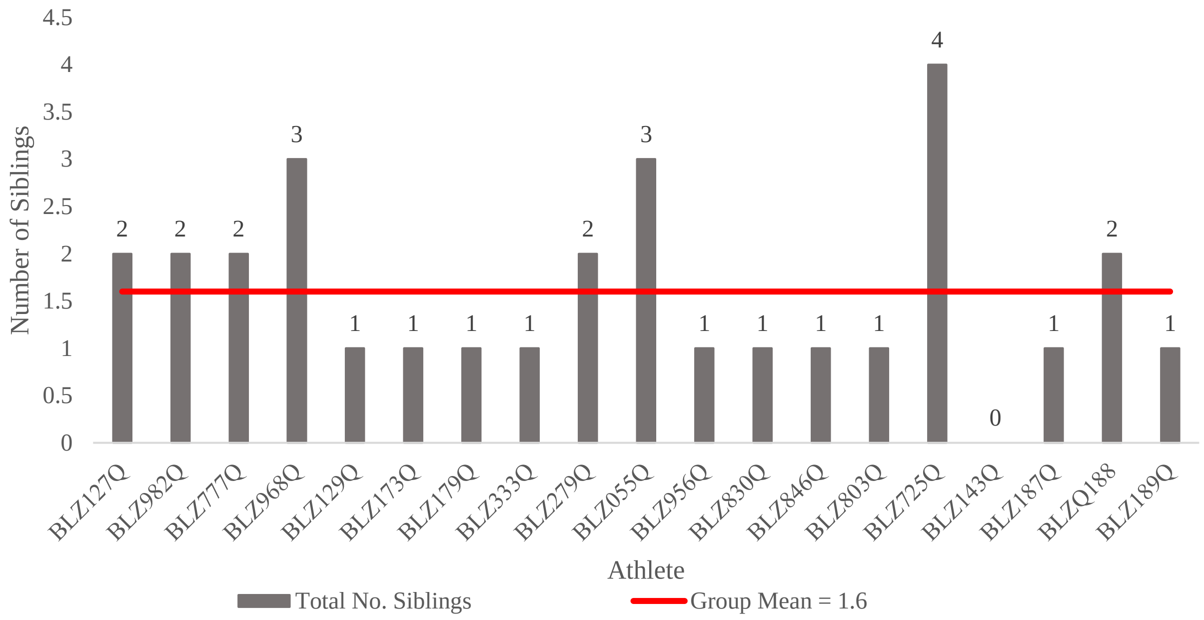

Figure 4.4. Group means and individual data for the overall number of siblings.

4.714 Sports during development

Figure 4.5 shows both the group mean, and the individual number of sports regularly participated or competed in during development. Early diversification is beneficial for development in elite sports where peak performance occurs post maturation. It is beneficial because it can help develop emotional, cognitive, and motor skills (Côté et al., 2012). The swimmer interview also highlighted their participation in multiple sports:

"I've always been sporty. Not just in swimming, just any sports, I used to do football, cricket, I did gymnastics at one time"

The current sample demonstrates a group mean of five other sports (not including swimming) and is consistent with the development of elite sporting expertise literature, especially the Developmental Model of Sports Participation (DMSP; Côte et al., 2009; Jean Côté, 1999). The range of sports participated in make it difficult to accurately identify 'donor sports' within this cohort, however, the most common sports included Athletics (53% of athletes), Football (47% of athletes), Netball and Cross Country (42% of athletes). Being clear on what role other sports play in an athlete's development, as well as when specialisation is/is not warranted, are important hallmarks of a successful development pathway (in being able to provide clear advice to parents and young athletes themselves).

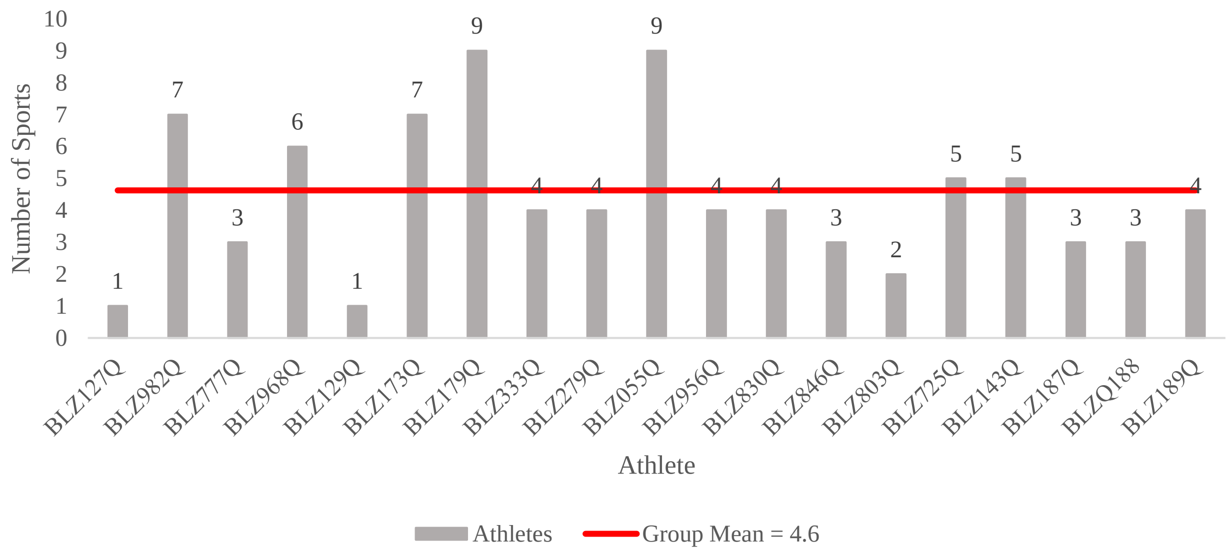

Figure 4.5. Group means and individual data for the number of sports participated in during development.

4.715 Swimming specific milestone ages

All athletes within this study had started swimming before the age of six. As shown in Figure 4.6, the athletes within this sample started competing in swimming at a mean age of 8.8 years, specialised in swimming approximately 4 years later (mean age 12.7 years) and then specialised in their event approximately 2 years later (mean age 14.3 years). These data are largely in line with the Developmental Model of Sport Participation (DMSP, Côte et al., 2009; Jean Côté, 1999). Whereby athletes of the Swim England Performance Programme specialised in swimming around the end of primary school (about age 13) and further specialised in their events once they developed the physical, cognitive, social, and emotional skills required to complete a high standard of specialised training (Côté & Vierimaa, 2014).

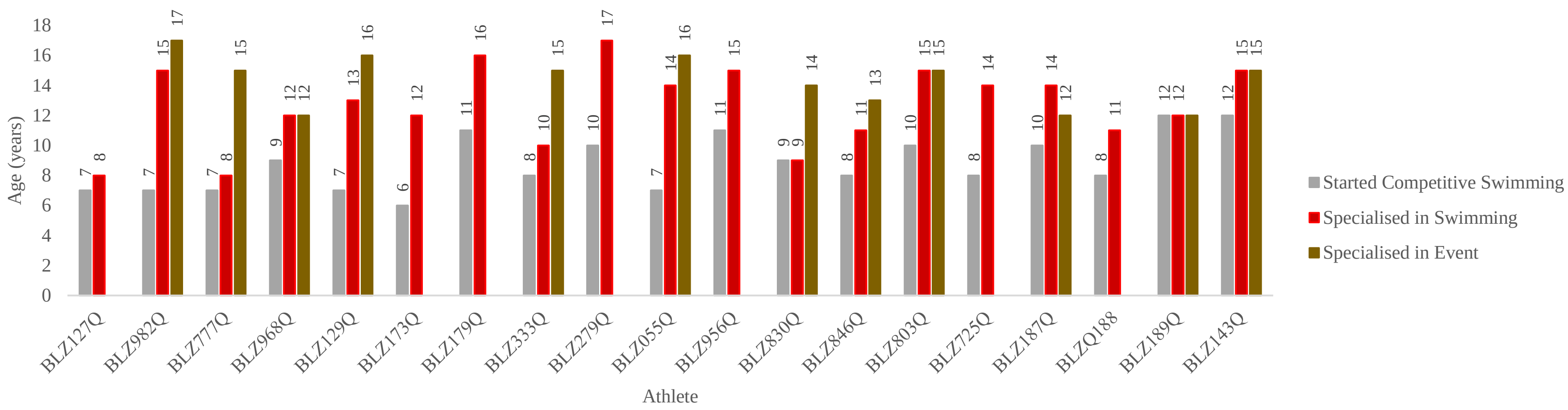

Figure 4.6. Ages of competition, sport specialisation and specialisation in events for individual athletes. There will be no data if a swimmer did not answer the question.

4.72 Practice and training in the pathway

Past research on expertise attainment has led to the development of the deliberate practice theory whereby hours spent in highly structured, goal-orientated, and supervised activity are theorised as a precursor to expertise (Baker & Young, 2015). However, recent research demonstrates that practice type, structure, and when practice occurs to influence the development of sporting expertise, in addition to the volume of practice completed (Jones et al., 2019).

From October 2019 to April 2021, we conducted a series of interviews regarding the athletes' practice and training activities. These interviews asked questions regarding the types of training and practice the athletes had done over multiple different time points. Mean data about the practice and training in the year before athletes joined the Swim England Performance Programme (September 2018-September 2019), and for every 3 months after are presented in the graphs below. COVID-19 caused an unexpected disruption to athletes' training and competition and so, we thought it was imperative to capture their experiences throughout this period. We interviewed athletes about their training in the first month of lockdown (April 2020) and the last month of lockdown (June 2020) before pools opening and therefore include this data where appropriate. The following section includes data from the main 16 athletes (10 females, 6 males, age 19.3 ± 1.9 years).

4.721 Context and anxiety specific training

Context-specific training: a practice that is similar to competition i.e., physiologically

Anxiety-specific training: a practice that is designed to simulate the pressure/anxiety of competition e.g., stand-ups

In pressured situations many athletes ‘choke’ (i.e., perform sub-optimally) despite high motivation to succeed (Baumeister & Showers, 1986). Choking can be reduced or sometimes even eliminated if performers practice under anxious conditions before performing under pressure situations (Nieuwenhuys & Raǒul, 2010). Evidence suggests that the benefits of practising with anxiety increase with the more pressured practice one complete (Lawrence et al., 2014). The data in Figures 4.7 and 4.8 highlights the mean proportions (red) of competition-specific context and anxiety specific practice alongside the individual variability perceived by athletes throughout various time points. On average, a small proportion of swimmer’s development training was completed under pressure conditions. However, on the transition into the Swim England Performance Programme, both the proportions of context and anxiety specific training increased.

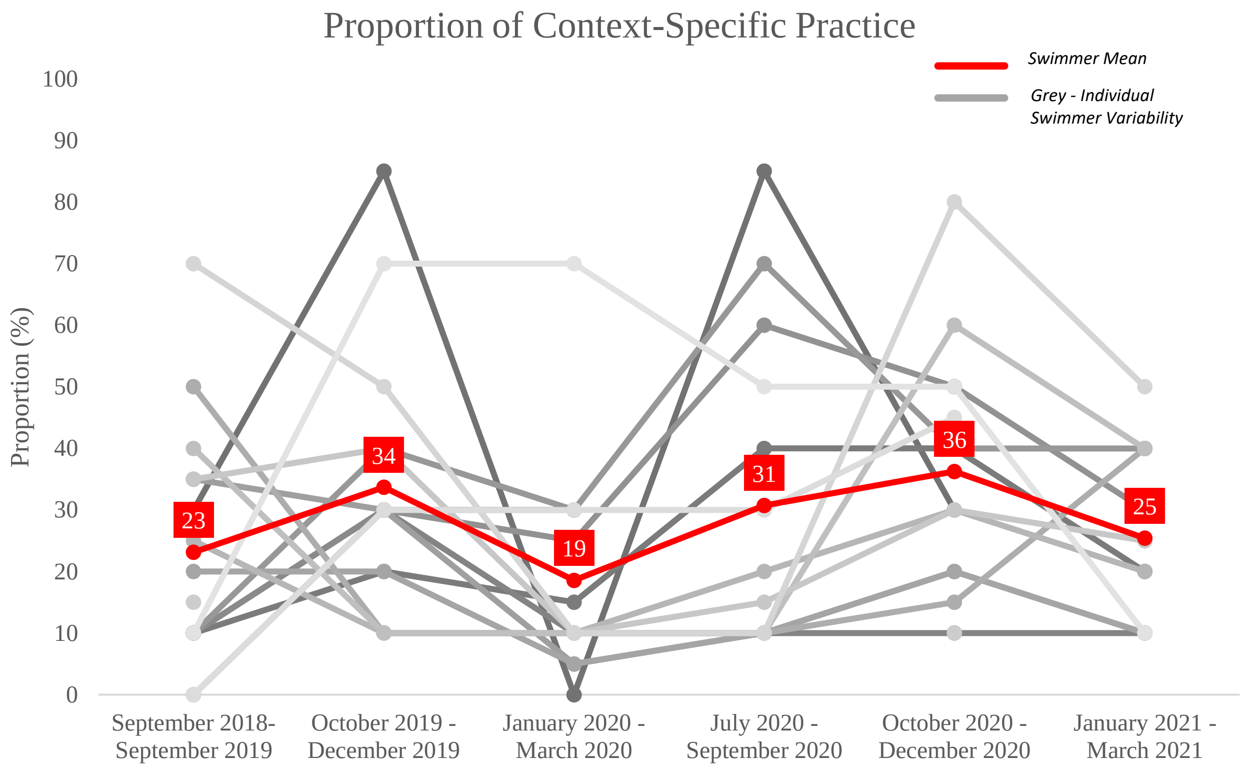

Figure 4.7. Proportions (%) of context-specific practice in the group (red line) and individual athletes (grey lines).

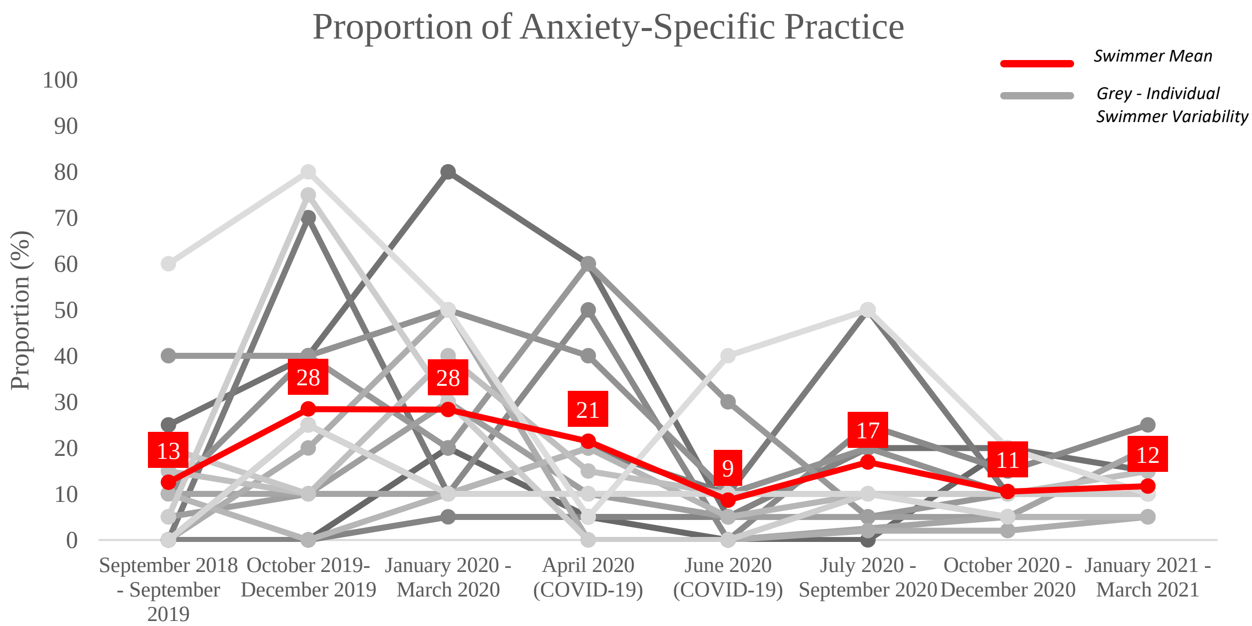

Figure 4.8. Proportions (%) of anxiety-specific practice in the group (red line) and individual athletes (grey lines).

4.722 Deliberate practice v deliberate play

Deliberate play: Free from focus inherently enjoyable and provides immediate gratification.

Deliberate practice: Highly structured activity that requires effort, generates no immediate rewards, and is motivated by the goals of improving performance rather than inherent enjoyment (Côté, Baker, and Abernethy, 2007).

As shown in Figure 4.9, on average (across all athletes) there was a higher proportion of deliberate practice in the sampling (age 6-12) and specialisation years (age 13-15) coupled with a decreasing proportion of deliberate play. However, at the start of lockdown, the proportion of deliberate play increased. The change of environment due to the closure of pools and gyms and the removal of coaches directing practice may have changed the context of training and thus, may have affected the types of training athletes engaged in throughout lockdown.

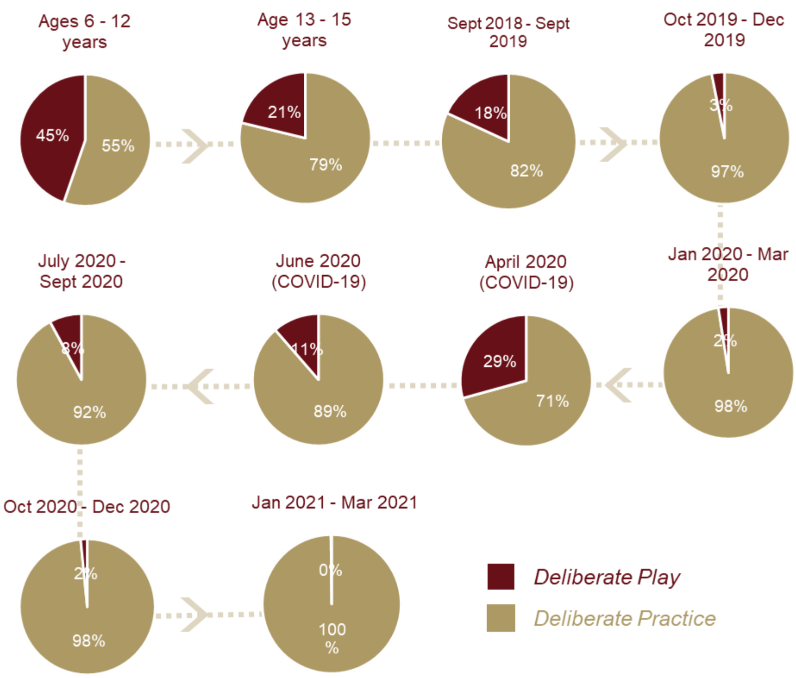

Figure 4.9. Data are presented as a group mean. The proportions (%'s) of deliberate practice and deliberate play throughout early years (6-12), specialisation years (13-15) for each swimmer, and the duration of data collection.

4.723 The proportion of prescriptive and constraints-led practice

Prescriptive coaching typically involves lots of demonstrations and verbal instructions about how to perform skills in a technically correct fashion, together with lots of feedback and guidance about how to adjust this technique on future attempts. A constraints-led approach to coaching is characterised by the manipulation of task (e.g., instructions, session goal) and environment (e.g., training equipment) boundaries or instructions (i.e., constraints). Task and environment constraints interact with each other and the intrinsic constraints of the performer to facilitate and guide movement (Newell, 1991). By manipulating task and environment constraints, coaches can guide athletes to find solutions to sports problems through exploration and discovery. The literature in this area suggests that constraints-led practice can develop adaptable performers who are more robust under competition settings (Renshaw et al., 2019). Alternatively, in coaching sessions, athletes may be encouraged to decide what their task goal is, and design and direct their task accordingly (swimmer-directed). Across the periods of data collection, it is evident that all types of coaching were used; however, prescriptive forms of coaching were dominant throughout (see Figure 4.10). That said, from October 2020 to December 2020, the volume of athlete-directed practice was high (59%, Figure 4.10). This finding could be a result of coaches not being allowed to be poolside due to COVID-19 related restrictions.

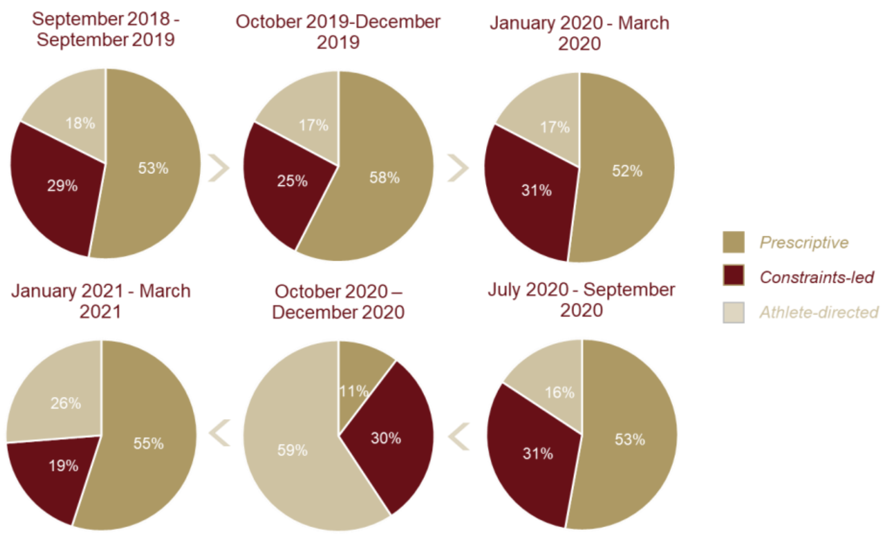

Figure 4.10. Group mean proportions (%) of prescriptive, constraints-led, and swimmer-directed practice throughout data collection.

4.724 Practice and training main findings

1. There is a relatively even split between the birth quartiles of the athletes within this study.
2. The most common sports during development included Athletics, Football, Netball, and Cross Country – early diversification in sports is fundamental to the development of foundational elements regarding motor skills (Côté & Vierimaa, 2014).
3. All athletes started swimming before the age of 6 years. The athletes within this sample started competing in swimming at a mean age of 8.8 years, specialised in swimming approximately 4 years later (mean age 12.7 years) and then specialised in their event approximately 2 years later (mean age 14.3 years) – specialising in swimming and their events were in line with the DMSP (Côté & Vierimaa, 2014).
4. A high proportion of deliberate play in the sampling years (6-12 years) is suggested to establish cognitive and motor skills, as well as build an individual's intrinsic motivation that allows for positive long-term involvement (Côté & Vierimaa, 2014).
5. It is evident that all types of coaching were used; however, prescriptive forms of coaching predominate. Prescriptive coaching may make error detection and correction difficult for the athletes (Smeeton & Seifert, 2020), so it might be worth coaches looking at ways of encouraging athletes to be more independent.
6. On average, a small proportion of swimmers' developmental training was completed under pressure conditions. However, on the transition into the Swim England Performance Programme, both the proportions of context and anxiety specific training increase. There may be some consideration as to how further increases in the amount of context and anxiety specific training affect athletes as they progress to national centres and how well 'prepared' they may be for the new environment of a national centre.

4.73 Psychosocial factors

Athletes and coaches completed a series of psychosocial measures including the Swimmer/Coach Development Formulation Survey (ADFS/CDFS) at the start of the project and a Prospective Psychosocial Survey (PPS) every six months thereafter.

In this study, we present comparisons between the coach and athlete psychosocial data and offer some recommendations regarding coach-athlete relationships. For completeness, we have provided definitions for each variable measured alongside group mean data for the ADFS and CDFS in Appendices 4.1, 4.2 and 4.3, respectively.

4.731 Prospective coach and swimmer comparisons.

All athletes completed the ADFS and first PPS, after which 88% and 78% of athletes completed the second and third PPS, respectively. Whilst swimmer adherence to these measures was good, coach adherence was poor with seven coaches completing both the CDFS and first PPS and 0 subsequent regular completions of the PPS. We therefore can only present meaningful comparisons between the group means of swimmer and coaches PPS data across the first time point collected in April 2020. That said, we ran a repeated-measures ANOVA examining 3-time points for the athlete PPS data (see appendices 4.8). The results indicated that despite disruption from lockdown, athletes' perceptions of support from their coaches did not change.

The results of these comparisons are presented in Table 4.1. In brief, both swimmers and coaches scored towards the higher end of the scale on all measures, indicating not only a high presence of these behaviours in coaches but that coach perceptions of their behaviours were largely interpreted in the same way by athletes. This similarity is important, as often coach and swimmer ratings of behaviours are not identical (Beattie et al., 2019). The swimmer interview also highlighted the perceived support they receive from their coach:

"Whenever she talks to you or tries to get you to do something, you just feel like you can do anything"

"I fully trust in her process of things"

She always stands by, "If you give me 100%, I'll give you 100%," and I think that's great. And I think, to be a great, successful coach, a lot of them should stand by that rule."

Further support for the high levels of perceived support was found in qualitative data collected from the coach practice and training interviews. These conversations suggested that some coaches were engaged with the holistic athlete rather than predominantly focusing on the prescription of training alone. For example, some coaches referred to the importance of understanding life outside of the swimming pool (e.g., school, family, and university) as well as utilising tools to measure menstrual cycles. That said there were some discrepancies in the data that warranted further investigation. The mismatch in data indicates that there is a small, but potentially meaningful, difference in what coaches think they are doing versus what they are being perceived to do by their athletes for some variables (Table 4.1). Generally, coaches scored higher than athletes across the variables. This finding could be due to a range of possibilities:

1. Coaches are overly positive in the perception of how they provide support to their athletes.
2. Athletes are overly harsh in their perceptions of the support provided by the coaches and perhaps have very high expectations of their coaches. It is somewhat unsurprising that athletes reported lower levels of behaviour than coaches given the high levels of perfectionism reported by these athletes and that high levels of perfectionistic strivings are considered a discriminator of performance progression in these athletes (Figure 4.12).

More specifically, there was a perceived difference in the extent to which coaches:

1. Develop, articulate, and inspire others with their vision for the future (inspirational motivation)
2. Lead by and set a good example (appropriate role model)
3. Provide positive reinforcement in return for appropriate behaviour and performance (contingent reward)
4. Provide optimal challenge and positive performance feedback in the environment (structure)
5. Provide respect and one feels cared for, included and secure in the environment (involvement)
6. Feel emotionally close with one other in the coach-swimmer relationship (closeness)
7. Engage in asking questions that encourage thought and reflection (effective questioning)
8. Provide support to help attain one's goals (goal setting)

Table 4.1. ***Tables of means for variables measured relating to the coach-swimmer relationship.***

	Athletes	Coaches	Cohens D
Individual Consideration	4.5	4.6	0.2
Inspirational Motivation *	4.2	4.9	1
Intellectual Stimulation	4.3	4.6	0.5
Acceptance of Group Goals	4.1	4.7	0.9
High-performance Expectations	4.6	4.4	0.3
Appropriate Role Model *	4.2	4.9	1
Contingent Reward *	4.1	2.9	2
Autonomy Support	4.3	4.6	0.4
Structure *	4.3	4.9	1
Involvement *	3.9	4.9	1
Commitment	4.5	4.6	0.2

Closeness *	4.5	3	1.7
Complementarity	4.4	3.5	1.1
Responsiveness	3.8	4	0.4
Effective Questioning *	4.1	3.2	1.2
Goal Setting *	4.3	4.9	1
Developmental Feedback	4.5	4.9	0.7
Motivational Feedback	4.5	4.7	0.4

*Note. * Significant difference between the swimmer and coach mean data at $p<0.05$ with large effect sizes (Cohens d).*

4.732 Psychosocial variables main findings

1. Both athletes and coaches scored towards the higher end of the scale on all measures, indicating not only a high presence of support behaviours in coaches but also that coach perceptions of their behaviours were largely interpreted in the same way by athletes. Such a high degree of similarity is not always the norm, so should be seen as a positive.
2. Athletes' perceptions are that coaches are doing a good job in supporting their needs. The predominantly high and consistent scores indicate that even throughout COVID-19, these perceptions did not change.
3. There are some minor discrepancies between athlete and coach perceptions. That is not to say that these relationships are poor, but the suggestions below may lead to an even more effective coach-athlete relationship.
4. The differences between goal setting and effective questioning point towards a requirement for athletes and coaches to communicate more regularly.
5. It is worth considering that many of these athletes score high on the perfectionism scales (see appendix 4.2) thus, some athletes may have unrealistically high standards for their coaches that cannot reasonably be met.

4.74 Training, recovery, and health factors

In this report, we present the mean athlete data regarding training, sleep and health for the data collection period and discuss the implications. All data are presented as means. We present the full data set with standard deviations in appendix 4.6.

4.741 Adherence

The average adherence throughout data collection was 70% (±22%). Individual swimmer adherence ranged from 30% to 100%, whilst weekly group adherence ranged from 31% to 100%. It should be noted that adherence rose from 33% (week commencing 25th October 2020) to 93% (week commencing 9th November 2020) when a personalised reminder via an online platform was sent on the final morning of completion.

4.742 Training

Athletes trained on average for 11 h 30 min in the pool, covering an average distance of 32 km per week. On top of this, athletes completed 4 h 37 min of land-based training and 1 h 25 min of competition per week. Athletes reported that this training involved hard exertion levels (6 out of 10), but they felt motivated (4 out of 5), ready to train most of the time (4 out of 5), and moderately recovered (6.5 out of 10) from the training completed. See appendix 4.6 for the full data breakdown.

4.743 Sleep

Generally, athletes obtained sleep of good to very good quality. Although, 61% of the time athletes reported that they struggled to get to sleep within 30 min of going to bed and 49% of the time athletes reported that they woke up throughout the night. On training days, athletes went to bed at 22:15, woke up at 06:36 and obtained 7 h 53 min of night-time sleep. In comparison, on rest days athletes went to bed at 22:39, woke up at 09:11 and obtained 9 h 27 min of night-time sleep. In addition, athletes reported that they napped at least one day per week for approximately one hour. Based on guidelines for the general population

(Hirshkowitz et al., 2015), the recommended amount of sleep is 8-10 h for 14-17-year-olds and 7-9 h for 18-25-year-olds. However, it should be noted that before 23rd March (first lockdown), athletes were obtaining an average of 7 h 5 min on training days with some only obtaining 4 h 30 min on some nights. The increase in sleep following 23rd March (see Figure 4.11) could be attributed to the closure of pools, meaning that athletes did not have to wake up as early for training and thus, were able to wake later, and therefore able to obtain more sleep.

4.744 Health

Athletes reported high levels of perceived wellbeing (73%), which is both higher than scores previously found in the general population (66%; Randall et al., 2019) and in a young elite athletic sample (58%; Ohlert & Ott, 2017). Further, these athletes reported low levels of perceived stress (24%), which was considerably lower than reported in the general population (38%; Warttig et al., 2013). The higher wellbeing and lower stress of pathway athletes are most likely indicative of adequate recovery and support from coaches and the Swim England Performance Programme itself.

At any given time, 14% of athletes reported a health problem, of which 6.2% of athletes reported an injury and 7.3% reported an illness. This equates to approximately two of the 16 athletes reporting a health problem at any given time. With regards to the availability of athletes to train and compete, throughout data collection, 87% of athletes were able to participate in training without any health problems, 7% of athletes were able to participate in training with no modifications but with a health problem, 5% of athletes had to modify their training due to health problems, and 1% could not participate in training due to health problems.

4.745 Training, recovery, and health main findings

1. The average completion of the weekly training questionnaire was 70% (±22%).
2. During COVID-19 athletes slept more. This finding further highlights that when not required to wake earlier for training, athletes chose to sleep more (Figure 4.11).
3. Whilst athletes obtain the recommended sleep quantity in line with the general population, these athletes may require greater daily sleep, especially considering that sleep is the key recovery strategy for all athletes (Halson, 2008).
4. Both sleep latency and sleep disturbance were prevalent (30% reported sleep latency and 49% reported sleep disturbance). The discrepancy between training and rest day sleep indicates that when possible athletes chose to sleep more.
5. Higher wellbeing and lower stress compared to the general population indicate positive mental health.
6. At any given time, approximately two of the 16 athletes experienced health problems. Whilst 94% of athletes were able to participate in training without any modifications due to health problems, 6% of swimmers had to modify their training due to or could not participate due to health problems. It is worth considering the impact of the training modifications or a lack of availability to athletes such that a lack of athlete availability to participate in training has been associated with profound consequences and can negatively affect game, match, or competition performance (Raysmith & Drew, 2016).

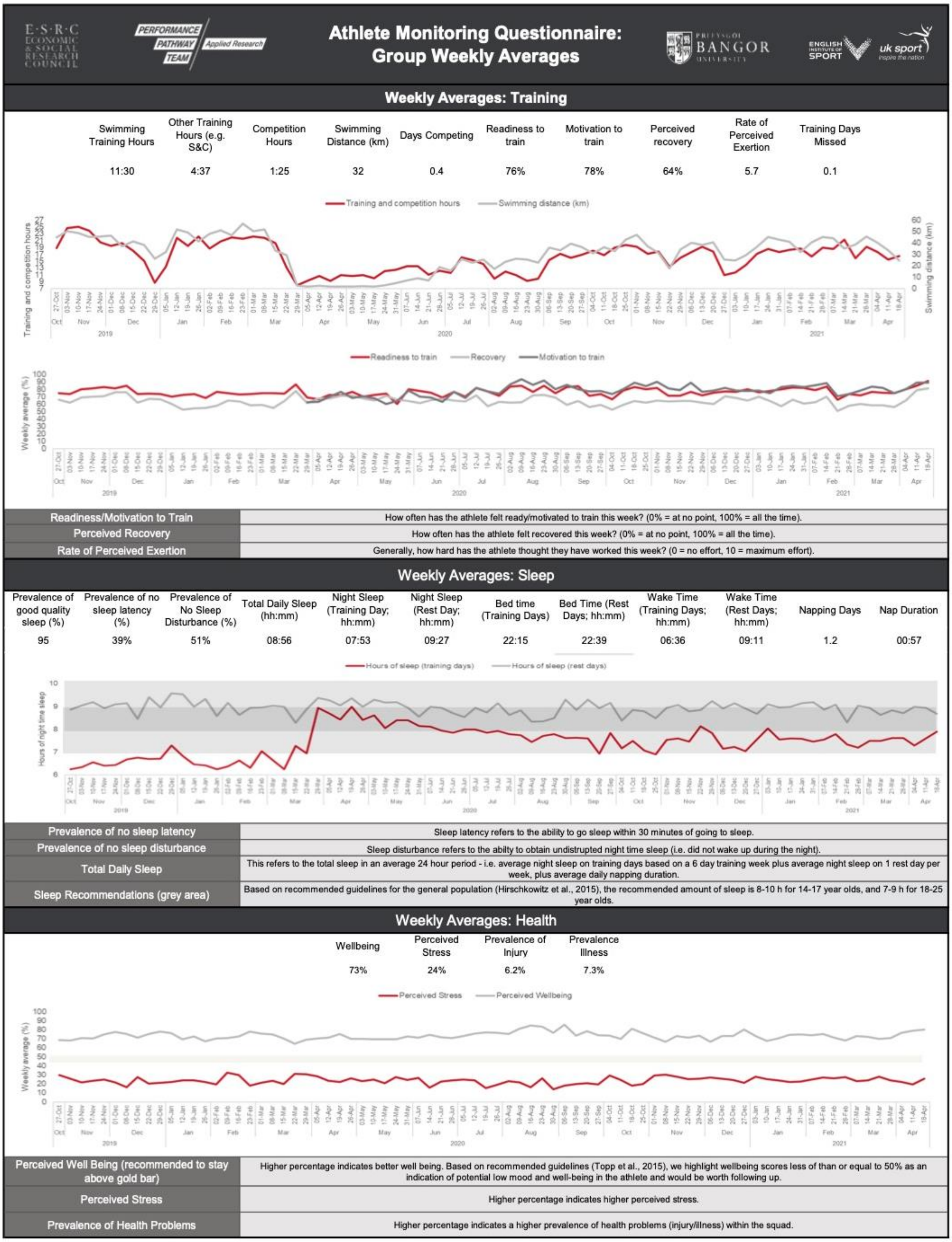

Figure 4.11. Overview of the group AMQ data

4.8 Part 2: Pattern recognition

Pattern recognition was originally developed in bioinformatics as a way of classifying objects depending on the features they possess (Hastie, 2009) but has been used more recently in sport to examine combinations of variables that are best able to discriminate between groups of individuals (e.g., multiple gold medal-winning athletes vs those who have represented their country at an international event, see Hardy et al., 2017). Pattern recognition requires that data be "split" into two groups, to determine the combination of variables that best explain the differences between these groups. Based on discussions with Swim England, we aimed to distinguish between athletes more likely to progress and thrive in the World-Class Programme using expert consensus from the coaches and pre-determined criteria from British Swimming**.** In the following section, we present four subsets of data that show which factors are best able to discriminate between athletes who were judged to be more likely to progress into the WCP compared to athletes that were judged to be less likely to progress (Table 4.2). These analyses include the examination of the full data set (practice and training, psychosocial, and training and health factors, Figure 4.12) and three subsequent analyses of each section alone (Figures 4.13, 4.14, 4.15) It is important to note that in these analyses, it is the combination of variables that discriminates between the groups and not any single variable or combination of variables outside of the whole pattern. Any visualisations are crude representations to aid the interpretation of these findings and may not represent the complex interaction between the variables.

Further considerations to the pattern recognition

- These patterns are a result of the selected classification variable (athletes who are more likely to progress through the high-performance system – higher potential – compared to athletes that were less likely to progress through the high-performance system – lower potential). A different pattern of discriminating variables would likely emerge if a different criterion were used.

- Sample specific. Due to the small sample of athletes, we do not yet know whether we could replicate these samples in another cohort of athletes, so these findings should be interpreted cautiously.
- Not all variables are selected in the overall model; however, this does not mean that they are not important. This analysis identifies the most important discriminating variables, so it is imperative to note that other variables may also be important to progression, but they may be *common* between both groups of athletes (i.e., all athletes need that variable to 'make it this far').
- Coach data have not been included as there was too much 'missing data.' Thus, the following analyses are based upon swimmer data alone.
- The mean classification rate refers to the rate at which each model correctly classifies a sample of athletes across the two groups (mean across three algorithms). We consider classification rates of 80% - 95% as good (Anderson, 2020) however, we discuss the applied meanings behind these classification rates in further detail below.
- The true positive rate refers to how many higher potential athletes were correctly classified as higher potential athletes.
- We include age within the main, practice and training, and health and wellbeing analyses due to the key developmental milestones and maturation effects that may occur between the ages of 16 – 24 years (Côté & Vierimaa, 2014). The maturation status of an individual determines physical attributes such as body height, body mass and physical fitness (Lesinski et al., 2020) and subsequently affects the performance and health of an individual (Towlson et al., 2021).

- Data points presented as part of the pattern recognition plot reflect the normalised mean values for each group (Figures 4.12, 4.13, 4.14 and 4.15). This transformation allows all variables to be displayed on the same scale

Table 4.2 ***Splitting of athletes based on the sports progression criteria***

	Higher Potential	Lower Potential
N	5	10
Age (mean ± SD)	18.2 ± 1.1	19.7 ± 1.8
Sex	2 Female, 3 Male	7 Female, 3 Male

4.81 Pattern recognition: full dataset

The first analysis is based on the whole data set of athlete variables. From the original 640 variables submitted to the analysis, a subset of only 9 variables were identified as discriminating between athletes more likely to progress (higher potential) versus athletes less likely to progress (lower potential) with a mean accuracy rating of 96% Figure 4.12). This model was able to classify 92% of higher potential athletes correctly as higher potential athletes (True Positive Rate, TPR). Table 4.3 shows the mean scores for the variables. Swimmer health and training data are considered across six-time points (T):

T1: 27/10/2019-25/01/2020

T2: 26/01/2020-25/04/2020

T3: 26/04/2020-25/07/2020

T4: 26/07/2020-24/10/2020

T5: 25/10/2020-23/01/2021

T6: 24/01/2021-19/04/2021

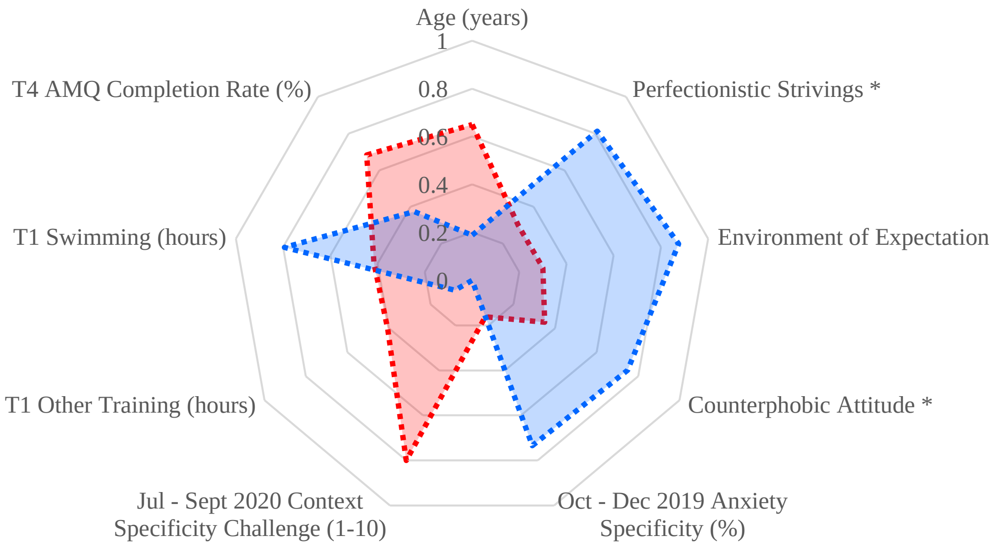

Figure 4.12. Full model discriminating between athletes more likely to progress through the high-performance system (higher potential, blue line) compared to those who are less likely to progress through the high-performance system (lower potential, red line).

Table 4.3. *Tables of means for variables identified within the full swimmer dataset.*

Variables	Lower potential	Higher potential
Age (years)	19.6	17.8
Perfectionistic Strivings *	7.2	9.3
Environment of Expectation *	6.2	8.5
Counterphobic Attitude *	5.4	7.0
Oct-Dec 2019 Anxiety Specificity (%)	13.0	58.8
Jul - Sept 2020 Context Specificity Challenge (1-10)	9.6	8.0
T1 Weekly Other Training Duration	4 hours, 24 minutes	1 hour, 48 minutes
T1 Weekly Swimming Duration	13 hours, 38 minutes	16 hours, 58 minutes
T4 AMQ Completion Rate (%)	68	38

Note. * Scored from 2-10

Summary of the full model pattern recognition.

The full model suggests that athletes are more likely to progress in the high-performance system (higher potential):

- Were younger.
- Had higher levels of perfectionistic strivings (holding oneself to high standards and striving for perfection).
- Reported a higher environment of expectation (i.e., exposed to an aspirational environment, or culture of achievement, during developmental years).
- Reported a higher counterphobic attitude (i.e., they thrive on or are drawn to intense emotions elicited in high-level competition).
- Completed more swimming training hours but less S&C (land-based training) in the first 3 months of data collection. Further, any training completed in the first 3 months

involved a greater proportion of anxiety specific training (i.e., mimicked the pressure they would feel at a meet).

- Had poorer completion rates of the AMQ in T4.
- Perceived any context-specific practice completed in July – September 2020 as less challenging.

4.82 Pattern recognition: psychosocial factors

The second analysis is based on the psychosocial swimmer variables only. From the original 90 variables submitted to the analysis, a subset of only 6 variables was identified as discriminating between athletes more likely to progress versus athletes less likely to progress with an accuracy rate of 80% (Figure 4.13). This model was able to classify 84% of higher potential athletes correctly as higher potential athletes (True Positive Rate). Table 4.4 shows the mean scores for the variables.

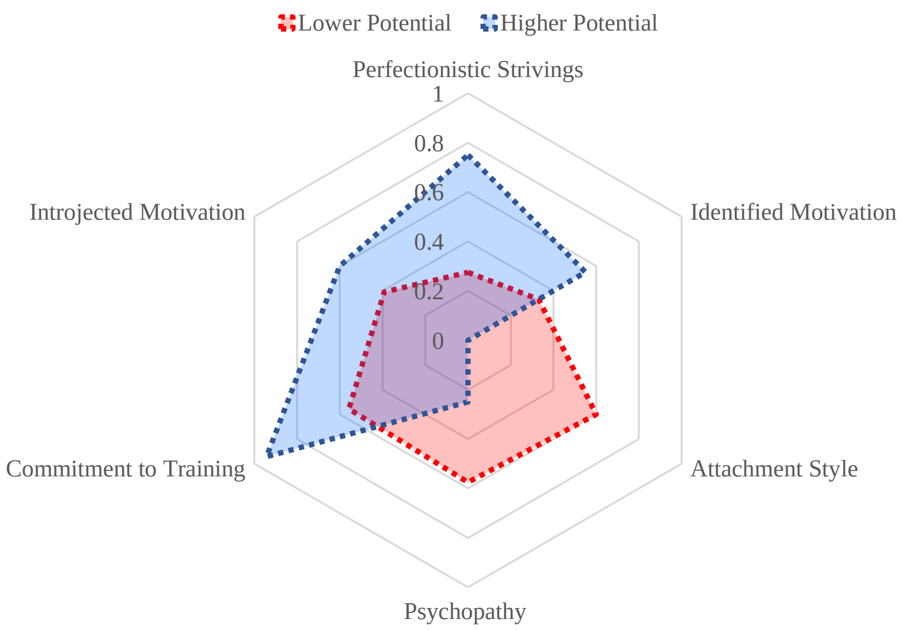

Figure 4.13. Swimmer psychosocial model discriminates between athletes more likely to progress through the high-performance system (higher potential, blue line) compared to those who are less likely to progress through the high-performance system (lower potential, red line).

Table 4.4. *Tables of means for variables identified within the swimmer psychosocial data.*

Variables	Lower potential	Higher potential
Perfectionistic Strivings *	7.1	9.0
Identified Motivation **	4.1	4.4
Introjected Motivation **	3.8	4.2
Attachment Style	Preoccupied	Secure
Psychopathy **	4.3	3
Commitment to Training *	6.9	9.6

Note. * Scored from 2- 10, ** scored from 1- 5.

Summary of the psychosocial pattern recognition.

The psychosocial model suggests that athletes are more likely to progress in the high-performance system (higher potential):

- Had higher perfectionistic strivings (holding oneself to high standards and striving for perfection).
- Had higher identified motivation (i.e., they are motivated to swim because they value swimming) as well as a higher introjected motivation/regulation (i.e., they are motivated to perform at least partly out of guilt because their self-esteem is contingent on performing).
- Had a higher commitment to training (i.e., they invested significant effort into attending and completing training sessions).
- Had a more secure attachment style (i.e., they had a positive view of the self with a positive view of others) whereas the lower potential group reported a more preoccupied attachment style (i.e. they had a negative view of the self with a positive view of others).
- Had lower psychopathy traits whereby psychopathy behaviours include rigid thinking and impulsiveness.

4.83 Pattern recognition: practice and training factors

The third analysis is based on the practice and training swimmer variables. From the original 314 variables submitted to the analysis, a subset of only 14 variables was identified as discriminating between athletes more likely to progress versus athletes less likely to progress with an overall accuracy rate of 100% (Figure 4.14). This model was able to classify 100% of higher potential athletes correctly as higher potential athletes (True Positive Rate). Table 4.5 shows the mean scores for the variables.

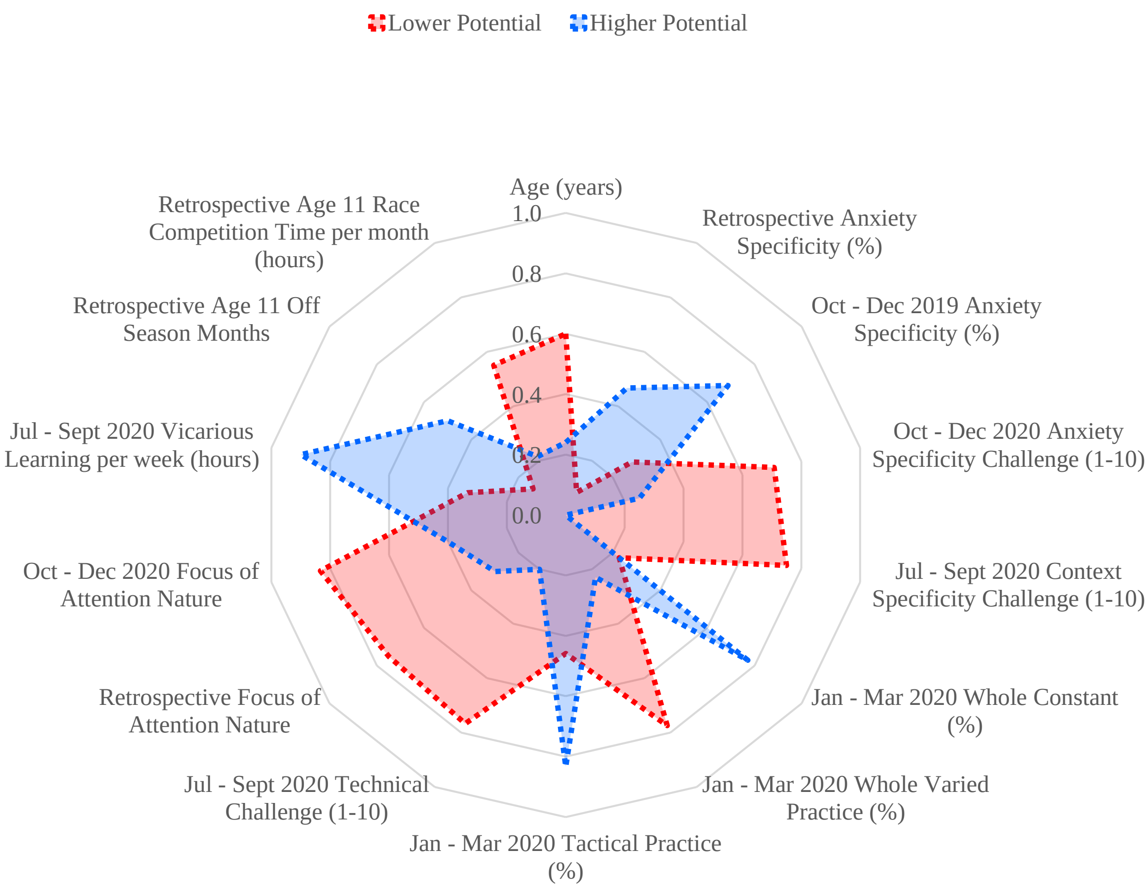

Figure 4.14. Practice and training model discriminating between athletes more likely to progress through the high-performance system (higher potential, blue line) compared to those who are less likely to progress through the high-performance system (lower potential, red line).

Table 4.5 *Tables of means for variables identified within the practice and training data*

Variables	Lower potential	Higher potential
Age (years)	20.0	18.2
Retrospective Anxiety Specificity (%)	5.0	28.0
Oct-Dec 2019 Anxiety Specificity (%)	22.5	55.0
Oct-Dec 2020 Anxiety Specificity Challenge (1-10)	8.8	7.0
Jul - Sept 2020 Context Specificity Challenge (1-10)	9.5	8.0
Jan - Mar 2020 Whole Constant (%)	35.8	74.0
Jan - Mar 2020 Whole Varied Practice (%)	64.2	26.0
Jan - Mar 2020 Tactical Practice (%)	52.5	75.0
Jul - Sept 2020 Technical Challenge (1-10)	5.8	3.0
Retrospective Focus of Attention Nature	Equal	Holistic
Oct-Dec 2020 Focus of Attention Nature	Equal	Holistic
Jul - Sept 2020 Vicarious Learning per week	12 minutes	30 minutes
Retrospective Age 11 Off-Season (months)	1.4	2.5
Retrospective Age 11 Competition time per month (hours)	15.4	6.0

Summary of the practice and training pattern recognition.

The practice and training model suggests that athletes are more likely to progress in the high-performance system (higher potential):

- Completed more anxiety specific training (i.e., mimics the pressure they would feel at a meet) in the year before joining the Swim England Performance Squad and from October 2019 to December 2019. However, any anxiety specific training from October to December 2019 was perceived as less challenging.
- Completed a greater proportion of whole constant practice (e.g., 10 x 100 m freestyle with same turnaround time) and a lower proportion of whole varied practice (e.g., 10 x 100 m freestyle with different turnaround times or varying pace/focus) from January

– March 2020. In swimming, constant practice may equate more to competition compared to varied practice.

- Completed more tactical based training (i.e., race-specific practice e.g., stand-ups) in January – March 2020.
- Perceived any technical practice or context-specific practice in July – September 2020 as less challenging.
- Reported greater volume of vicarious learning from July – September 2020 (e.g., watching others swim, watching swimming on YouTube).
- Competed less and had a longer off-season at age 11.
- Had more of a holistic focus of attention in training in the year before joining the Swim England Performance Squad and from October to December 2020 (i.e., think about how the body moves as one rather than zoning in on different body parts).

4.84 Pattern recognition: health, training, and availability

The fourth analysis is based on the health, training and availability variables collected from the athletes. These data are considered across six-time points:

T1: 27/10/2019-25/01/2020

T2: 26/01/2020-25/04/2020

T3: 26/04/2020-25/07/2020

T4: 26/07/2020-24/10/2020

T5: 25/10/2020-23/01/2021

T6: 24/01/2021-19/04/2021

From the original 201 variables submitted to the analysis, a subset of only 13 variables was identified as discriminating between athletes more likely to progress versus athletes less likely to progress with a mean accuracy rate of 74% (Figure 4.15). This model was able to classify 67% of higher potential athletes correctly as higher potential athletes. Table 4.6 shows the mean scores for the variables.

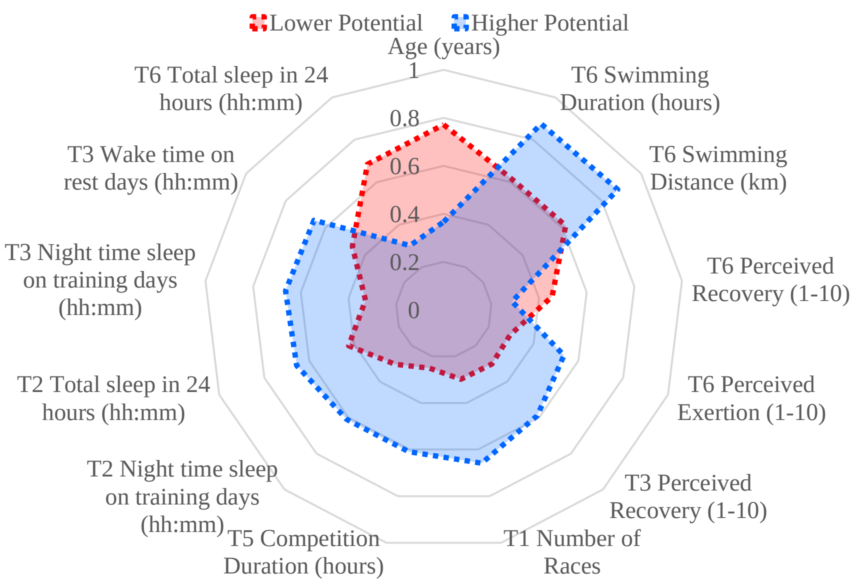

Figure 4.15. Health, training, and availability model discriminating between athletes more likely to progress through the high-performance system (higher potential, blue line) compared to those who are less likely to progress through the high-performance system (lower potential, red line).

Table 4.6 *Tables of means for variables identified within the health, training, and availability data*

Variables	Lower potential	Higher potential
Age (years)	19.9	17.8
T6 Swimming Duration	12 hours, 17 minutes	17 hours, 29 minutes
T6 Swimming Distance (km)	35.5	50.7
T6 Perceived Recovery (1-10) *	6.4	5.9
T6 Perceived Exertion (1-10) *	5.4	6.7
T3 Perceived Recovery (1-10) *	6.4	7.5
T1 Number of Races	1.5	2.5
T5 Competition Duration	33 minutes	1 hour, 22 minutes
T2 Nighttime sleep on training days	7 hours, 24 minutes	8 hours, 19 minutes
T2 Total sleep in 24 hours	8 hours, 8 minutes	8 hours, 44 minutes
T3 Nighttime sleep on training days	9 hours, 1 minute	9 hours, 54 minutes
T3 Wake time on rest days (hh: mm)	09:13	09:52
T6 Total sleep in 24 hours	8 hours, 54 minutes	8 hours, 15 minutes

*Note, Perceived Recovery (0 = very poorly recovered, 10 = very well recovered), Perceived Exertion (0 = at rest, 10 = maximal)

Summary of the health, training, and availability pattern recognition.

The health, training and availability model suggests that athletes are more likely to progress in the high-performance system (higher potential):

- Completed more swimming training hours and km, and competition hours in the last 6 months of data collection.
- Slept for longer on rest and training days and wake up later on rest days.
- In the last 3 months, these athletes slept for slightly less in 24 hours, perceived their training to be of higher effort and perceived themselves as less recovered. The perceived higher efforts and lower recovery are unsurprising considering the high volume of swimming and competition hours.
- Completed more races in the first 3 months of data collection.
- The higher potential group obtained more sleep in 24 hours during T2. T2 was a lockdown period whereby athletes had limited access to pool training, thus, higher potential athletes may have utilised the lack of early morning training by obtaining more sleep. Whilst higher potential athletes napped less during T2, they obtained more night-time sleep on both training and rest days compared to the lower potential group.
- The opposite was found in T6 whereby lower potential athletes obtained more sleep in 24 hours than the higher potential group. T6 was more reflective of a race block with athletes completing various meets throughout. The breakdown of sleep suggests that higher potential athletes slept for less on training days, more on rest days, and napped less frequently but for a longer duration.

4.9 Part 3: Qualitative data on culture

4.91 Introduction and aim.

According to the Competing Values Theory (Quinn & Rohrbaugh, 1981), a high-performance system is centred on four competing themes: achievement, wellbeing, innovation, and internal processes. Jones et al. (2009) defined each of these as follows: 1) Achievement - a focus on productivity and the attainment of goals, whether that be performance or progression; 2) Wellbeing - relating to the development of people within an organisation; 3) Innovation - emphasis on creativity; 4) Internal Processes – an emphasis on formalization and internal control of systems and procedures. An organisation striving to attain a high-performance environment is required to balance the values of these four themes, however, at any given time some will take priority over others.

4.92 Method

To obtain data regarding the intended or desired culture and the philosophy underpinning talent identification and development within Swim England Talent, we conducted a semi-structured interview with their HoT. This interview consisted of a series of questions and prompts about philosophies, coaching, swimmer selection/deselection, and the four main themes: health, achievement, internal processes, and innovation. The researcher conducted this 60-minute interview with the HoT in January 2020. After some initial open questions, the HoT was asked a series of pre-determined prompting questions about the themes. The semi-structured approach allowed the researcher flexibility in the flow of the interview but ensured that all the themes were covered to the required depth. Once transcribed, the researcher followed a scientifically underpinned and rigorous process to extract the data and discuss the findings and implications. After reading the transcript several times, a deductive approach (Braun & Clarke, 2008) was employed to break down the interview into meaningful exerts indicative of each theme. Two ‘critical friends’ (cf. Sparkes

& Smith, 2004) were utilised at key points to cross-check the themes and ensure the extracted quotes corresponded to their allocated theme and no other information was missed. The data were subsequently reanalysed and summarised by the lead researcher then presented back to the two ‘critical friends’ with further discussion about the themes, and the implications of the findings.

4.93 Findings

The five identified themes - Innovation, Wellbeing Achievement, and Internal Processes - were evident throughout the interview. In the following sections, we discuss the HoT’s interpretation of each theme using direct quotes.

4.931 Innovation

This programme tends to follow processes passed down from British Swimming as extensive research and resources inform these processes. For example,

“We tend to do what we’ve done in the past, and that’s been reasonably successful, but that’s also quite dull… some things are tried and tested that we do, but whether we actually reinvent the wheel along the way, I’d probably argue that we don’t”

When talking about swimmer selection processes, the HoT explained that these are guided by research from British Swimming. For example,

“We do know that to win a [swimming] medal in a particular event in Paris [Olympic Games 2024], you need to be a certain age”

The HoT acknowledged that as a developmental programme, they would like to be more innovative in how they select and develop a specific group of athletes, rather than the masses. For example,

"Our innovation needs to change from the masses to a smaller group of people, a lot more bespoke and a lot more focused"

4.932 Wellbeing

Whilst the HoT did not refer to their programme as particularly innovative, he felt that the programme had evolved and adapted as the needs of the swimmer, the coach and the sport developed, particularly with swimmer mental health and coach development needs. Health, in particular mental wellbeing, had been the recent focus of this programme and its resources.

"We took a decision then to do a mental health screen, and the assumption with that was if you're going to do that, you've got to be prepared to do something with the results"

Whether it is help from a physiotherapist, a lifestyle advisor, a nutritionist or a psychologist, this process was created to address any clinical concerns as soon as possible. However, whilst the health of the athletes was a current focus, the HoT acknowledged areas for improvement regarding coaches' wellbeing.

"We've been criticised from a coaching perspective, as well as a national governing body, about trying to support coaches with mental health issues"

In recent years, Swim England have put together a programme that aims to support the developmental needs of coaches but does not yet provide support for the mental health and wellbeing of coaches. The HoT suggested that this is something Swim England would like to address soon.

4.933 Internal Processes.

The formalisation of structure and processes (internal processes) was not a current area of concern as these were already well established. Athletes or coaches, therefore, know what resources are available and who to contact should a problem arise.

"Our processes are well established now, so most people would know who to go to…what's come out of the UK health check is that our systems are visible, highly visible. So, people would know who to interact with"

4.934 Achievement.

The achievement in the Swim England pathway focuses on the ability of athletes to successfully develop and transition through the high-performance system, rather than the number of medals.

"It's one of our KPIs [Key Performance Indicators], how many people do we get from phase three or performance squad to transition to podium potential? So, that's the achievement for me"

"I would suggest in the past all we're worried about is medals, or finals, or best times and things like that."

The HoT acknowledged that this programme may not appear successful, as currently, no athletes have transitioned on to podium potential. However, the HoT reiterated the importance of this intermediary programme.

"It is right and proper that Swim England have a performance squad of some shape or form to keep people in the sport, to allow them to transfer, they may be late developers, and I don't want them going off into the wilderness"

The programme aims to generate athletes that can continue with a long and successful career in and out of the swimming environment by utilising a holistic approach.

"They're on this squad obviously to get results in the future, but the emphasis is to improve whatever you've got so that the results come later on"

"Our optimal swimmer development framework looks at the person, the swimmer, the performer…developing the person way outside of athletic development…to get hold of a person and to make them understand, this is just one of life's journeys"

4.935 Balance.

Once all the areas were covered, the HoT was asked a final question regarding how they balanced all those themes within their environment (e.g., "Could you tell me about whether you feel that the culture in your sport focuses on several (all) of these aspects or prioritizes some aspects over others?").

"While we're trying to create decent human beings, we're also trying to fine-tune what the training programme looks like, what the psychology programme looks like, what the S&C and the support programmes look like as well, to get to the point where people can unblock and be confident that they're as good as the next person and so on"

Following which they were asked to split their current focus (between 100%) across the four themes depending on their current priorities. It should be noted that this interview was conducted in January 2020 and the focus on these themes may well vary depending on the time of the season. Figure 4.16 demonstrates the focus of this programme as of January 2020. The focus on each of these themes will be in constant flux depending on the aims and philosophies of the sporting environment but above all else, it appears the balance is influenced by access to resources (e.g., time and money). The HoT's focus is related to the development of people within an organisation (wellbeing). There was an equal emphasis on creativity (innovation) and on formalisation and internal control of systems and procedures (internal processes) with the least focus on productivity and the attainment of goals whether that be performance or progression (achievement). The perceived focus across the four components supports the philosophies of the Swim England programme in that it allows all swimmers the time, space, and developmental opportunities to transition to the world-class programme. Further, these philosophies are congruent with the idea that talent identification and development is not always linear, direct, or fast. Thus, it stands to reason that a programme of this nature exists and allows potential athletes to develop at their own pace.

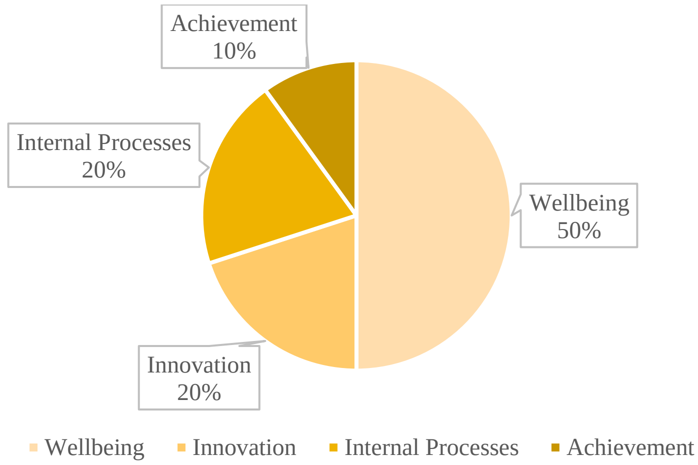

Figure 4.16. The weighted value of each theme according to the HoT of the Swim England Performance Squad as of January 2020.

4.10 Key findings and suggestions

These results provide us with the first truly holistic understanding of the most important development factors for Swim England athletes. Below we present the key findings from the pattern recognition, quantitative and qualitative data alongside potential evidence-based suggestions. A summary infographic of the end of sport report findings for England Swimming is provided in Figure 4.17.

Sleep

Sleep is considered an important discriminator in these athletes. Higher potential athletes slept for longer on rest and training days and woke up later on rest days. Further, the higher potential group obtained more sleep in 24 hours during T2. T2 was a lockdown period whereby athletes had limited access to pool training, thus, higher potential athletes may have utilised the lack of early morning training to obtain more sleep. Whilst higher potential athletes napped less during T2, they obtained more night-time sleep on both training and rest days compared to the lower potential group. The opposite was found in T6 whereby lower potential athletes obtained more sleep in 24 hours than the higher potential group. T6 was more reflective of a race block with athletes completing various meets throughout this period. The greater sleep in lower than higher potential athletes in T6 might be explained by a lower volume of competition and training in lower than higher potential athletes.

The breakdown of sleep suggests that higher potential athletes slept for less on training days, more on rest days, and napped less frequently, but for a longer duration.

The lower quality and quantity of sleep reported by some of these athletes may contribute to lower recovery and higher perceived effort during training. This supports the idea athletes might need to obtain more sleep and that Swim England might review their current sleep recommendations. Current recommendations are for the general population whereas training athletes may need more sleep.

Recommendations to Swim England could include reducing sleep disturbance and latency by educating athletes on good sleep hygiene, and by considering moving training times where possible so athletes can obtain more night-time sleep and encouraging daytime napping. Alternatively, Swim England could look to include a form of periodised sleep throughout the year in line with training cycles. For example, coaches may place a greater focus on sleep and recovery during high-intensity training blocks and/or in the lead up to important competitions.

Challenge

Any technical practice or context-specific practice (i.e., practice that closely mimics the pressure and environment of that in competition) from July 2020 to September 2020 was perceived as less challenging by higher potential athletes. This suggests that it is important that training involves anxiety and context-specific practice but perhaps: 1) the higher potential athletes are not challenged enough, or 2) the lower potential athletes perceive things as more challenging. A consideration for Swim England coaches is that training should be challenging both mentally and physically for all athletes but based on their requirements.

If athletes are more counterphobic (drawn to intense emotions elicited in high-level competition) they might find any challenge-based training easier because the anxiety training recreates something that they are naturally drawn to, it is, therefore, possible these higher potential athletes, who report high counterphobia, enjoy the training more and find it less challenging. Alternatively, if the high potential athletes do more challenge training, they might report finding it easier simply because of having had more experience with it (i.e. because they are more skilled/able to deal with the training).

To make training more challenging, a coach may utilise more constraints-led coaching as opposed to prescriptive coaching. A constraints-led approach is characterised by the manipulation of task (e.g., session goal) and environment (e.g., training equipment) boundaries or instructions (i.e., constraints). By manipulating task and environment constraints, coaches can guide athletes to find solutions to sports problems through exploration and discovery.

Coach-athlete communication

It is positive to see that swimmers' and coaches' needs as assessed in the psychosocial questionnaires are generally in agreement (indicating that coaches are generally successful in meeting the needs of their athletes). Because of small discrepancies found in the coach-athlete relationships data, we suggest regular communication with coaches and athletes before training camps and competitions on what their developmental and performance aims are. For example, the camp focus in Luxembourg in 2020 was more on mastery, whereby athletes were encouraged to try something new over the competition rather than the outcome (i.e., it wasn't just about winning medals). However, many athletes reported being disappointed with their results (i.e., the outcome) in Luxembourg. Nevertheless, athletes report a more mastery focus on the pathway so Swim England should be reassured that the athletes' aims are broadly in line with the pathway aims.

We suggest that coaches and support staff reiterate the goals and aims of a meet/competition regularly before and during. Further, the goals and aims must be mirrored vertically and horizontally throughout the pathway whereby there is a shared understanding and aim between all people at a given time-point, such that the athlete experiences consistent (and not contradicting) messages.

Mental health

The data indicate that Swimmer wellbeing is higher, and stress is lower than in the general population as indicated in the AMQ data. It is important to note however that when coaches were asked whether they thought the organisation cared about their wellbeing and opinion, most disagreed. This was also acknowledged as part of the HoT interview.

Continuing to monitor factors such as these regularly feels important to ensure that any clinical concerns with current and future athletes are quickly understood and supported (e.g., in a similar way to how ongoing musculoskeletal niggles / injuries would be treated by a physiotherapist). A recommendation for Swim England is to implement some strategies to support wellbeing that they have used with athletes but with the coaches as well. Something as "light-touch" as a quick check-in every few months to ask how coaches are coping by an appropriately trained and experienced person could be very effective here, as such check-ins would allow the sport to understand how coaches are feeling and would at the very least allow them to signpost if any issues arise.

Early racing

Higher potential athletes completed fewer monthly race hours and had a longer off-season at age 11 compared to lower potential athletes. Fewer racing hours at such an early age could also benefit athletes in their long-term athletic careers with less chance of burnouts and the development of injury (Côté et al., 2012).

This finding indicates that athletes do not necessarily need to complete an excessive number of race hours at a young age, which is contrary to the popular view that swimming is an early specialisation sport.

Psychological profile

The personality pattern shows a combination of discriminators between higher and lower potential athletes. Overall, this pattern suggests that higher potential athletes are achievement orientated, hardworking, highly committed to training (e.g., turn up on time and always put in a good performance), actively engage in their relationships, are highly motivated and are ‘easy’ to coach. The personality profile of these higher potential athletes is suggestive of a likeable and coachable individual/role model athlete. Lower potential athletes on the other hand reported a preoccupied attachment style and higher psychopathic traits. A preoccupied attachment style suggests that athletes have a negative view of self but a positive view of others. Coupled with a more dichotomous way of thinking and higher ruthlessness, the lower potential athletes may be perceived to be harder to coach and less likeable individuals. Whilst athletes of this profile are certainly likely to be more difficult to coach and work with, it is noteworthy that these traits are some of those that are found in super-elite athletes (Hardy et al., 2017). Similar findings are found in the study of elite rugby union players (Turner, 2021).

Swim England may want to consider who they are selecting/progressing and potentially losing as part of the selection process because of perceived personality characteristics and ease/difficulty to coach. The personality profile of the lower potential athletes is in line with those of some previous super-elite athletes thus, we suggest that Swim England look at ways in which to support the coaches of these athletes and the athletes themselves to maximise their development and their ability to achieve their potential.

The combined identified and introjected motivation suggests that higher potential athletes are motivated. An individual with introjected motivation may engage in activities due to guilt or to maintain their self-worth. This type of motivation is like an obsessive passion and is associated with high achievement (Vallerand, 2012). However, introjected motivation alone is associated with burnout and maladaptive progression (Pelletier et al., 2013). Identified motivation suggests that one engages with a task because they see the importance of the behaviour to themselves (Pelletier et al., 2013). Both must come out as discriminators, as identified motivation might help offset any problematic aspects of introjection and allow the benefits to come out.

It would be beneficial to coaches and Swim England to find out what motivates their athletes to train and compete. This could be done through regular conversations between athletes and coaches. Furthermore, coaches could make clear how training/practice/race activities are important for the development of athletes so that athletes know why they are doing certain things and why they are likely to be helpful.

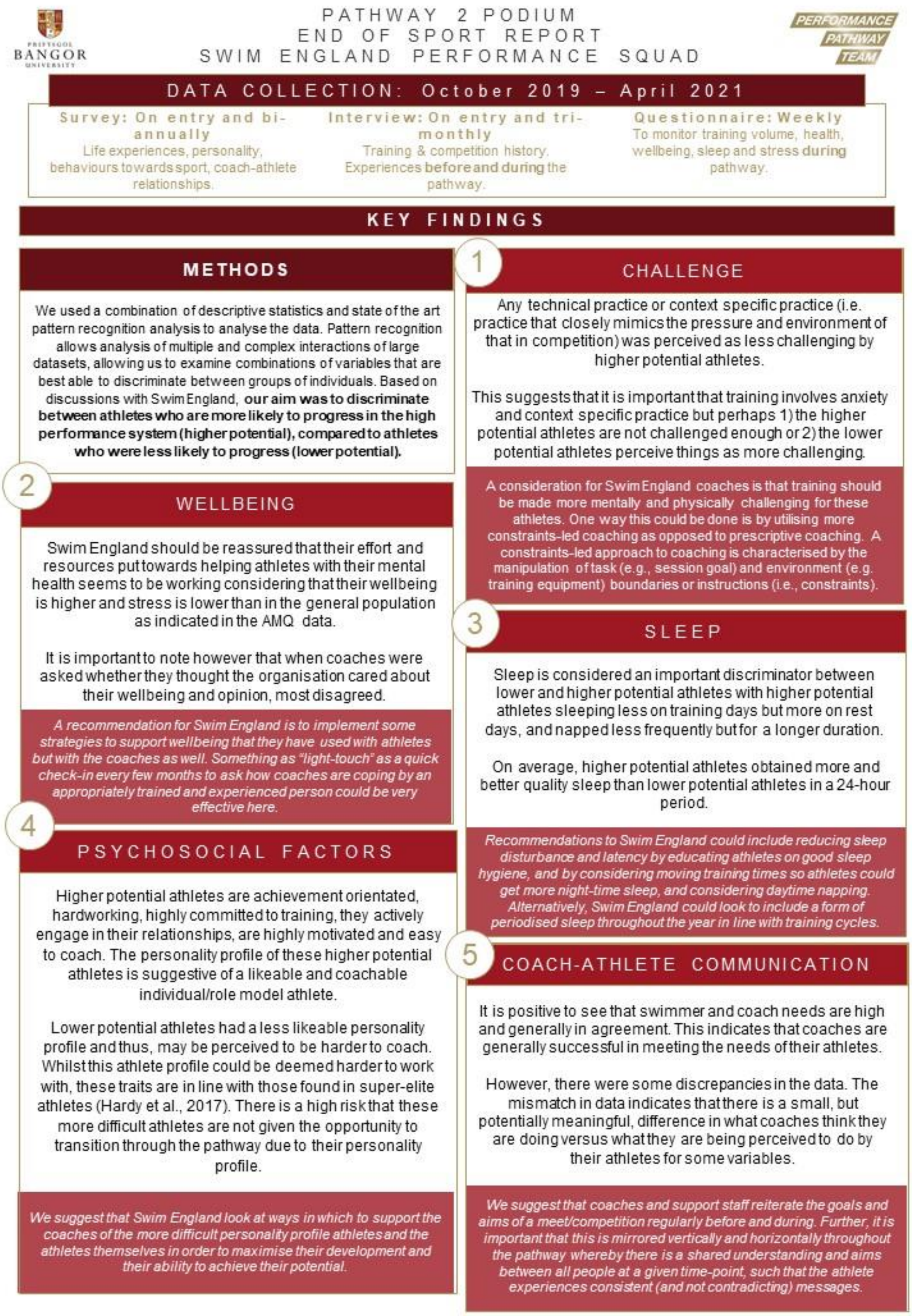

Figure 4.17 Summary infographic of the end of sport report findings for England Swimming

Chapter 5: General discussion

5.1 Overview

The present research aimed to advance understanding as to the importance of athlete availability in the talent development process of developing elite athletes. The secondary aim was to establish the determinants of athlete availability in developing elite athletes by creating a new multidimensional athlete-monitoring tool. The final aim was to examine the importance of variables such as sleep, wellbeing, and health in the context of talent development.

The general discussion is formed of five parts. Part 1 outlines the main findings from Chapters 2-4. Part 2 discusses the combined interactive meaning of these chapters together. Following this, I discuss the applied implications of these findings (Part 3) and I describe some considerations when interpreting the results of this PhD (Part 4). Finally, I go on to discuss the future directions of this research (Part 5).

5.2 Main thesis findings

5.21 Main thesis finding 1: athlete availability is higher in developing elite compared with NF athletes.

The primary aim of Chapter 2 was a comparison of two related groups relating to the determinants of (un)availability to train and compete in DE and NF athletes using the AMQ. In comparison with age-matched NF athletes, developing elite athletes were more available to train and compete. We found that developing elite athletes were able to complete higher weekly training volumes at a higher perceived effort but with a lower prevalence of injuries than NF. In addition, we found that developing elite athletes demonstrated higher wellbeing, lower stress, greater sleep duration, better sleep quality, greater perceived recovery, and greater readiness to train than NF athletes. In comparison, NF athletes completed high volumes of training yet had poor sleep behaviours, reported higher levels of injury, lower wellbeing, and higher stress levels thus, were less readily available to train and compete. An additional wider finding within this study was that the AMQ appears to have considerable utility as a measure of athlete availability with minimal time burden. Thus, for a marginal effort by the athlete, practitioners can glean substantial amounts of information regarding an athletes' training, health, and wellbeing status.

5.22 Main thesis finding 2: the determinants of athlete availability are best understood via a multidimensional approach

The aim of Chapter 3 was to identify the combination of variables that best discriminated between the training availability (i.e., availability to complete the prescribed training session to an optimal standard) of a cohort of developing elite swimmers. I assessed athlete availability in two ways. The first method focused on a swimmers' ability to train in the absence of health problems, while the second acknowledged that athletes may have an underlying health problem but could have no effect on training. By using pattern recognition, I was able to apply a holistic approach to analysing the complex interactions of multiple variables associated with a developing elite swimmers' availability. From many variables, the pattern recognition analyses identified key variables as discriminators between more and less available swimmers. Swimmers who were more available to train either with or without health problems completed higher volumes of training had better health and wellbeing (lower prevalence of health problems, higher wellbeing and motivation, and lower stress), and experienced better quality of night-time sleep (i.e., they did not wake up at night and could fall asleep within 30 minutes). Each of the patterns presented in the results included at least one variable related to training parameters (e.g., rate of perceived exertion), sleep, and health. These findings support the idea that athlete availability is not determined through unidimensional constructs; rather availability is best understood via a multidimensional approach, which considers (at least) training, sleep, and psychological factors.

5.23 Main thesis finding 3: athlete availability did not discriminate between lower and higher potential swimmers

Chapter 4 considered all factors (e.g., psychosocial, practice and training, health, and demographics) in the P2P project to establish the combination of variables that best discriminated between higher potential (swimmers who are likely to go on and succeed in the high-performance system) – and lower potential (swimmers less likely to continue in the high-performance system) swimmers. Contrary to our expectations, athlete availability did not come out as a discriminator between lower and higher potential swimmers. However, mean scores suggested that the higher potential swimmers were more available with fewer health problems when compared to the lower potential swimmers. What is more, both lower and higher potential developing elite swimmers were more available than NF athletes (Chapter 2), providing further support for main thesis finding 1.

5.3 Main implications

It is evident from our research that athlete availability is underpinned by a combination of different interactive factors. Athlete availability, or lack of, is not simply the result of poor sleep quality, diminished sleep quantity, poor mental health, or the failure to recover optimally from high training volumes. Rather, it is a complex interaction of a host of training, health, and sleep factors. For example, Chapter 3 discusses the combined higher levels of wellbeing, lower stress and greater motivation of athletes who did train more, which likely facilitated a high volume of effortful training. Accordingly, it is vital to measure and therefore consider the holistic and interactive effect of all possible variables together. Practitioners looking to understand their athletes should therefore consider adopting a multidimensional tool like the Athlete Monitoring Questionnaire, or at the very least, implement measures of sleep, health, and wellbeing.

5.31 Are certain factors important at different times of an athlete's sporting career?

When thinking about the thesis chapters together, we broaden our understanding of the importance of injury and illness in the talent development process. Our findings support the idea that certain factors are more important at different times of an athlete's sporting career. What may determine the ability of a developing elite athlete's availability could be considerably different to that of an elite senior athlete. Whilst this thesis cannot provide data on the differences between developing and senior elite athletes, we can gain insight into differences lower down the elite sporting pathway (i.e., the transition to developing elite). For example, the findings from Chapter 2 suggests that developing elite athletes train harder and for longer but with fewer injuries than an age-matched NF population. This finding speaks to the idea that athlete availability is an important factor in developing talent and being a high-level performer. One reason for this could be that these developing elite athletes have access to resources to work around injuries and illnesses (e.g., physiotherapists and medical staff) and so, the impact of health problems on athlete availability could be minimised.

The findings from Chapter 4 demonstrate that when we examine the potential of developing elite swimmers alone, health problem prevalence is not a discriminating factor between those more likely to progress versus those less likely to progress. Therefore, the lack of difference in the athlete availability between the progressions of developing elite athletes becomes somewhat negligible later in the pathway. That is not to say availability is not important, but perhaps developing elite athletes must be available to succeed to that level and thus, would not have progressed otherwise. That said, mean scores provided in Chapter 4 suggested that the higher potential swimmers were more available with fewer health problems when compared to the lower potential swimmers. This finding does not indicate that the availability to train and compete is not important, rather the findings suggest that other factors are currently *more* important within this model. These other factors (e.g., sleep and wellbeing) are discussed in the next section. Alternatively, in the context of performance progression, athlete availability could be a ’slow burner’ discriminator whereby, the effects of an athlete’s availability do not fully emerge until later in their career. For example, the benefits of an athlete being more available in their development years may not be apparent at the time of this study however, their availability may contribute to their performance and achievement later in their sporting career.

5.32 The importance of sleep and wellbeing in availability and talent development

In combining the results of the thesis chapters, it becomes apparent that variables such as sleep, and wellbeing dominate the results of the pattern recognition analyses. I discuss the implications of the combined chapter findings below.

5.321 Sleep quality

According to the data and method of measuring athlete progression, our findings suggest that sleep quality is important for athlete availability but does not discriminate between the progression of these developing elite swimmers. Chapter 3 revealed that sleep quality discriminated between the availability of developing elite swimmers to train without modifications due to health problems. These findings indicated the importance of sleep whereby to experience fewer health problems, obtaining good sleep quality may help the recover from the higher training loads completed by these swimmers. Alternatively, poor sleep quality could have had a detriment on a swimmer leading to a higher prevalence of health problems and poorer availability. On the other hand, a higher prevalence of health problems and poorer availability could lead to poor sleep quality. Simply put, sleep quality is important if a sport wants to minimise health problems and optimise athlete availability. However, when we consider talent development, similar to athlete availability, sleep quality was not a determinant of performance progression between lower and higher potential developing elite swimmers. The descriptive results of Chapter 4 suggest that all developing elite swimmers, regardless of progression grouping, reported a high volume of sleep latency and disturbance (i.e., cannot go to sleep within 30 minutes and wake up during the night) thus, indicating lower levels of sleep quality. Sleep quality could be a ’slow burner’ discriminator whereby, the effects of an athlete’s sleep quality do not fully emerge until later in their career. It would be worth investigating this finding in further research to see if the effect is robust and replicated across other sports and measures of progression (e.g., objective performance marker) across a longitudinal period.

5.322 Wellbeing

A current debate in elite sporting literature is whether elite sport is good for the wellbeing of athletes (Lebrun & Collins, 2017; Souter et al., 2018). However, categorising elite sport as either ‘good’ or ‘bad’ for wellbeing is an overly simplistic summary of a complex phenomenon. As opposed to trying to understand if sport is “good” across the pathway, it would be more beneficial to understand the conditions and variables associated with sport being ‘good’ or ‘bad,’ at different levels of the pathway so we (as researchers) can then help sports to put the right things in place to support athletes. Knowing these implications may aid our understanding as to what is ‘good’ or ‘bad’ with regards to mental wellbeing in athletes. Although we only had data from four pathway sports, the data in Chapter 2 suggested that these sporting pathways managed their athlete's training, wellbeing, and health well. Further investigation into the developing elite swimmers within Chapters 3 and 4 revealed that elite sport, at least for this squad, is okay for wellbeing. The average wellbeing score for developing elite swimmers was 73%, which compares favourably with scores previously found in the general population (66%; Randall et al., 2019) and in a young elite athletic sample (58%; Ohlert & Ott, 2017). The high levels of motivation and ‘readiness to train’ reported by developing elite swimmers in Chapter 3 speak to a positive mindset (Hamlin et al., 2019), which may well also be reflected in the higher levels of wellbeing and lower levels of stress. This may be attributed to a large focus of resources on swimmer wellbeing as reported in the qualitative interview of Chapter 4. Further, the assessment of coach-athlete relationships in Chapter 4 indicated that athletes generally felt that their coaches supported their basic psychological needs (e.g., autonomy, competence, and relatedness). This finding is important as previous research demonstrates that athletes’ wellbeing is higher when they perceive their basic psychological needs are satisfied (Davis & Jowett, 2014). While we have some evidence in other sports that being in the pathway ‘is good for wellbeing’ (i.e., based on the differences between pathway and NF athletes in Chapter 2), we do not understand of the mechanisms as to why in those other sports. Nor do we know the replicability of this finding in sports outside of the P2P project. An interesting consideration for future research and a point of speculation for coaches and support staff is whether this finding continues throughout the transition up the pathway. Whilst we cannot answer this as part of the P2P project, it is a good consideration for future research.

Chapter 3 identified the importance of a positive mindset (concerning training) and the ability to adapt to training stimulus (reflected in the perceived readiness to train, perceived recovery, and perceived motivation to train) being important for the availability of swimmers to train without modifications due to health problems. Similarly, the results of Chapter 4 suggested that whilst higher progression swimmers did not report higher levels of perceived readiness to train, nor perceived recovery (not surprising considering the greater volume of more effortful training), they reported higher levels of motivation compared to the lower progression swimmers. These combined findings suggest that to be available to train without modifications and to progress as a swimmer, motivation is important to withstand possible setbacks associated with the greater volume of more effortful training. Whilst we do not measure motivation to withstand setbacks directly, previous research has established a link between the importance of being able to deal with setbacks in training and performance progression (Beattie et al., 2019; Woodman et al., 2010).

5.4 Limitations of our research

5.41 Consideration 1: measure development

Due to the nature of research in the elite sporting field, we continually had to strike a balance between scientific integrity and real-world use. Thus, there are several empirical limitations surrounding the work contained in the thesis. Firstly, we developed our measures to meet several criteria including validity, reliability, and utility in the sporting environment. For example, we utilised previously validated measures where appropriate (e.g., using the WHO-5 Wellbeing Index to measure wellbeing). However, we required an alternative method where the regular completion of the full-validated measure (e.g., PSQI) was too burdensome for athletes and therefore may hinder the adherence/data collection. Hence, we selected questions from validated measures based on item relevance, and comprehensibility (Horvath & Röthlin, 2018). This process was completed in collaboration with sporting practitioners from the English Institute of Sport to provide an indication of the construct we wanted to measure from validated measures, and therefore, had good face validity. There would be considerable benefit in extending this work by utilising gold-standard measures of the variables collected as part of the AMQ and comparing the results against the AMQ. At present, a study of this nature was not feasible within the applied elite sporting populations participating in this study.

5.42 Consideration 2: grouping variables

Whilst the use of pattern recognition analyses is a strength of this research, we must acknowledge that the results of the pattern are likely somewhat a result of the selected grouping variable (e.g., progression or availability). A different grouping variable would produce a different pattern and therefore, a different combination of discriminating variables. The chosen grouping variable in Chapter 4 was between athletes who were judged to be more likely to progress into the World Class Programme (WCP) compared to athletes that were judged to be less likely to progress (from the viewpoint of the head coach). Ideally, I would have corroborated this subjective marker of progression with objective performance data (e.g., race results). However, due to Covid-19 and the lack of competitive meets, I was unable to obtain objective performance data. Therefore, the cross-examination of the head coaches' 'gut-instinct' with performance results was not possible. That said, the process of athlete selection within these programmes is not purely based upon numerical scores (i.e., race results) rather, the selection is based upon the perceived potential of an athlete dependent upon their ability to meet the sports outline criteria. It would be beneficial for future research to utilise and compare an objective and a subjective approach to performance progression grouping.

5.43 Consideration 3: COVID-19

Coronavirus disease 2019 (COVID-19), a respiratory disease, caused a worldwide pandemic from December 2019 onwards. On the 23rd March 2020, the UK went into its first 'lockdown' whereby citizens were instructed to 'stay at home' until further notice to prevent the spread of the disease. The government lifted the restrictions of lockdown 1 in early June 2020 allowing developing elite swimmers (athletes) to return to their pool and gym training environments. Due to a continuous rise in COVID-19 infection rates, England was placed under further lockdown restrictions throughout November 2020, and again from late December 2020 until 29th March 2021. There was concern that my PhD would be disrupted due to COVID-19 however, as examined and explained in Chapter 3, a reader can have confidence in the generalisability of the thesis findings as opposed to the findings being solely a result of the pandemic and lockdown.

5.44 Consideration 4: sample size

A noteworthy limitation is the representativeness of athletes and sports who provided data for this project. As discussed in Chapter 3, I acknowledge that the sample size limits the generalisability of our findings. However, I utilised all the available athletes of the given developing elite populations. With that in mind, I remind the reader that the findings of this thesis are limited to the studied population, which is until further research can be completed to replicate and extend upon our findings. Nonetheless, the use of smaller sample sizes and sporting populations allows for an in-depth examination of many variables. If this research had been conducted with larger sample sizes, I would have had to take a more 'broad-brush' approach to our data collection method which would have reduced the ability to take an in-depth approach to understanding outcomes in these sports.

5.45 Consideration 5: female specific considerations

A final consideration of this thesis is the exclusion of female-specific factors regarding health and performance. It is suggested that the menstrual cycle influences athletic performance (see Carmichael et al., 2021 for a narrative review). That said, there are inconsistencies within the literature regarding the phase of the menstrual cycle that causes a change in physical and psychological performance. A recent review by McNulty et al (2020) concluded that whilst performance may be reduced during the early follicular phase of the menstrual cycle, this is trivial and therefore, a conclusive guideline cannot be formed. The complexities of hormonal tracking, individual cycle changes and hormonal contraceptives have confounded the current literature leaving high-quality research somewhat lacking. With access to a cohort of developing elite youth female athletes this PhD would have benefitted from the inclusion of female-specific consideration.

5.5 Implications for Sports Scientists and Researchers

The benefit of a combined theoretical and applied research focus means that we can provide valuable applied and theoretical implications for sports practitioners and the research field, respectively. Within this thesis, I have discussed the applied and theoretical implications of each chapter individually; however, there are a series of broader applied implications relevant to sporting organisations, coaches, and athletes when we view the chapters as one.

5.51 Implication 1: education, communication and cohesion between all bodies connected to the athlete is paramount

The findings of this thesis continually highlight the need to take a holistic approach to athlete monitoring and availability. Therefore, sporting bodies should look at educating coaches and support staff on the holistic nature of availability, so that all support staff can be "joined-up" in their support of athletes. In addition, from the thesis findings, we know that there is a differential effect on athlete availability at different time points of an athlete's career and that athlete availability is determined by different variables throughout an athlete's career. Regular communication between the coaches, athletes, and support staff etc., about the goals and aims of a programme, will similarly enhance the support of athletes.

As discussed in Chapter 2, the success of athlete monitoring tools is largely dependent on athlete adherence. Anecdotal evidence from this chapter suggested that adherence was better in those with coach/ support staff engagement who received and utilised the weekly feedback forms. We therefore would encourage the use of regular feedback to athletes, the recruitment of coaches/support staff in the feedback process and more importantly, the education on how to best utilise the AMQ (and feedback, or other monitoring tools) in future use.

5.52 Implication 2: injury prevention is important for athlete availability

The extent to which health problems limit the availability of an athlete to train and compete is important at any stage of an athletes' career (i.e., whether in the early NF years or further down a specialised sporting pathway). Therefore, early in athlete progression, there is a need to develop physical resilience (opposite of injury/illness prone) to health problems. Practitioners should look to focus particularly on injury prevention considering that Chapter 2 data supports that being injury (but not illness) resistant is important for athlete availability. The provision of education, support and appropriate medical support is one way in which to develop this resilience.

5.53 Implication 3: the importance of obtaining adequate sleep quality and quantity cannot be underestimated

The results of this thesis provide support for previous research that sleep is one of the most important recovery tools for athletes (Halson, 2014). Whilst the concept of obtaining sufficient quantity and quality of sleep is easy to understand, it is often poorly executed. Previous research has provided ample support for this (Leeder et al., 2012), as well as our findings within the developing elite swimmers of this thesis. We, therefore, encourage education for athletes, coaches, and support staff (including family) on how to prioritise sleep as a recovery tool.

In addition to education, athletes and coaches should take a more considered approach to training times. Early morning training times are a common occurrence with athletes (NF or developing elite) that must fit in training before work, school, or university, or are dictated by the facility availability times (Sargent et al., 2014). Not only does early morning training have the potential to curtail sleep quantity but the knowledge of getting up early disturbs sleep quality (as demonstrated by the high prevalence of sleep latency and disruption evident in the findings in the thesis). It is also possible that the increased sleep latency reported by these athletes is a result of athletes trying to go to bed early to compensate for the early wake-up time. What is more, research shows that the sleep pattern of adolescents is hormonally influenced and therefore, shifts towards a natural tendency to go to sleep and wake later (Shochat et al., 2013). Early morning training is not helpfully placed to work well with this. It, therefore, allows speculation as to why athletes are required to train so early, especially considering the data-supported physiological rationale to train early morning is poor (Sargent et al., 2012). Sports could consider a shift in training times to accommodate this essential recovery technique in their athletes.

5.6 Future directions

This thesis has begun to advance the theoretical understanding between athlete availability and talent development; however, there is a need to further explore the role of availability across the different stages of a developing elite athlete's career up until senior elite status. One novel aspect of the P2P project was the collection of data over a longitudinal period such that researchers would collect data from the participating sports for multiple years (e.g., 2 years plus). In some sports, data collection was limited to 6 months due to coach and athlete adherence. Meanwhile, we were able to collect approximately 18 months to 2 years of data from other sports (e.g., Swimming, Hockey, Canoe Slalom, and Canoe Sprint). Whilst this meant that we could extract a host of meaningful findings, we are still unable to answer some questions regarding athlete availability and the progression of developing elite athletes from junior to senior programmes. It would be beneficial for future research to examine whether the findings of this thesis regarding availability and progression would still apply as these athletes transition up the pathway.

The findings of Chapters 2 and 4 warrant further investigation. Whilst availability to train without health problems or any modifications to training due to health problems did not come out as a discriminator between an athletes' progression, this does not mean that it is not an important variable. Rather, within this pattern, there were more important discriminating variables between higher and lower potential athletes. Despite availability not appearing in the pattern, it is worth noting that when considering the descriptive data alone, the higher potential athletes were more available without health problems over all time points and the prevalence of health problems was lower (Chapter 4). In contrast, lower potential athletes had lower availability without health problems and a higher prevalence of health problems across all time points. In addition, descriptive data from Chapter 2 revealed that developing elite athletes were more readily available compared to NF athletes. Therefore, further exploration of the combined findings of Chapters 2 and 4 would lend a greater understanding of athlete progression and availability. This further research may also look at using an alternative grouping variable (e.g., performance-based on objective data) for the developing elite athletes. This was beyond the scope of this thesis due to a lack of performance results in the latter half of data collection (due to COVID-19).

As discussed as part of the considerations of this thesis, there would be a benefit in extending the validity work on the AMQ by utilising gold-standard measures of the variables collected as part of the AMQ. At present, a study of this nature was not feasible within the applied elite sporting populations participating in this study. We also believe that further revision to the AMQ would be worthwhile. As discussed in Chapter 3, future iterations of the AMQ may look to consider differences in sleep quality and quantity before rest and training days, collecting detail regarding the intended and actual days of training per week, and finally, an athlete should be able to report alternative reasons for unavailability to train such as holidays, family, work, or school commitments. that should be amended for future use Further, it would be worth including other variables (e.g., motivation to deal with setbacks) that we have not explicitly measured in the thesis yet seem important. Finally, as discussed in the Considerations section of the discussion, future work would benefit from the inclusion of female-specific considerations, for example, menstrual cycle calendar and symptom tracking. This inclusion would not only provide insight into the individuals menstrual cycle and associated performance but would contribute to the movement towards breaking the gender-bias gap that exists with sport science literature (Smith et al., 2022).

5.7 Concluding remarks

This thesis aimed to answer three overall questions: 1) How does athlete availability differ between NF and developing elite athletes? 2) What are the determinants of athlete availability in a developing elite athletic population? and 3) How important is athlete availability, sleep, wellbeing, and health in the context of talent development and progression? Through the completion of several studies, I was able to answer these questions and form a series of applied implications for practitioners.

The conclusion of this thesis is that athlete availability is an important factor in developing talent and being a high-level performer. However, the difference in availability becomes somewhat negligible later in the pathway. That is not to say availability is no less important, availability influences progression at an early stage of athlete development and thus, an athlete would not have progressed otherwise. A consistent finding throughout this thesis is that athlete availability is not determined through unidimensional constructs; rather availability is best understood via a multidimensional approach, which considers (at least) training, sleep, and psychological factors.

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Appendix and supplementary material

Appendix

Supplementary material: PhD impact and dissemination

Appendices 2.1: Participant characteristics

Characteristics	**Developing Elite athletes**	**Non- funded athletes**
Number of participants	42	79
Sex	17 male (41%), 25 female (59%)	23 male (29%), 56 female (71%)
Age (years) (SD)	20.8 (2.5)	22.0 (2.1)
Sport	British Rowing: n=13; Swim England: n=16; British Canoe Slalom: n=8; British Canoe Sprint: n=5	Rowing: n=2; Dance: n=1; Trampolining: n=1; Climbing: n=3; Pole Fitness: n=2; Squash: n=2; Hockey: n=18; Badminton: n=4; Running: n=4; Netball: n=5; Lacrosse: n=1; Gymnastics: n=2; Weightlifting: n=5; Triathlon: n=1; Basketball: n=3; Horse Riding: n=1; Boxing: n=1; Martial Arts: n=6; Cheerleading: n=2; Football: n=1; Swimming: n=3; Gaelic football: n=1; Rugby: n=3; Volleyball: n=1; Gym: n=6.

Some data are presented as mean (standard deviation). A t-test revealed that these groups were age-matched $p = 0.762$

Appendices 3.1: Athlete Monitoring Questionnaire (AMQ)

You are about to complete a monitoring tool that asks about your training, recovery, sleep, overall wellbeing and any injury, illness or other health problems experienced over the past week (*depending on completion day detail the day from and to e.g., Monday to Sunday).* Please try to answer the questions as thoroughly and as honestly as possible. There are no right or wrong answers. Your answers will not affect your position on the programme.

TNFINING:

Please take a few seconds to think back over the last week of training. Think about where you spent most of the time training, who you trained with, and the most memorable session of the week. It may help you to have your training diary with you to aid completion.

Question 1:

How many hours of the following have you completed in the past week?

- Hours of sport-specific:
- Hours of other training (e.g., gym, weights, yoga, rehabilitation etc.):
- Hours of competition:

Question 2:

Please briefly describe the types of training that you have been doing in the past week.

____

____

____

Question 3: (If relevant)

How many kilometres (km) have you *covered* in the past week?

Question 4:

How many days have you competed on this past week?

Question 5:

How many times have you raced/competed?

Question 6:

Over the past week, how often have you felt ready to train?

- All the time (5)
- Most of the time (4)
- More than half the time (3)
- Less than half the time (2)
- Some of the time (1)
- At no time (0)
- I have not trained (6)

Question 7:

Over the past week, how often have you felt motivated to train?

- All the time (5)
- Most of the time (4)
- More than half the time (3)
- Less than half the time (2)
- Some of the time (1)

- At no time (0)
- I have not trained (6)

Question 8:

Over the past week, how well recovered have you felt?

- 0 Very poorly recovered (0)
- 1 (1)
- 2 Not well recovered (2)
- 3 (3)
- 4 Somewhat recovered (4)
- 5 Adequately Recovered (5)
- 6 Moderately Recovered (6)
- 7 (7)
- 8 Well Recovered (8)
- 9 (9)
- 10 Very well recovered (10)
- I have not trained (11)

Question 9:

Over the past week, what has been your overall perceived exertion?

- 0 At rest (0)
- 1 Very, very easy (1)
- 2 Easy (2)
- 3 Moderate (3)
- 4 Somewhat Hard (4)
- 5 Hard (5)

- 6 (6)
- 7 Very Hard (7)
- 8 (8)
- 9 (9)
- 10 Maximal (10)
- I have not trained (11)

HEALTH:

Please answer all questions regardless of whether you have experienced health problems in the past week. Select the alternative that is most appropriate for you, and in the case that you are unsure, try to answer as best you can anyway.

A health problem is any condition that you consider to be a reduction in your normal state of full health, irrespective of its consequences on your sports participation or performance, or whether you have sought medical attention. This may include, but is not limited to, injury, illness, pain, or mental health conditions. If you have several health problems, please begin by recording your worst problem in the past 7 days. You will have a chance to register other problems at the end of the questionnaire.

Question 10a: Participation

Have you had any difficulties participating in normal training and competition due to injury, illness, or other health problems during the past week?

- Full participation without health problems (injury/illness) (0)
- Full participation, but with injury/illness (8)
- Reduced participation due to injury/illness (17)
- Cannot participate due to injury/illness (25)

Q10b: Modified training/competition

To what extent have you reduced your training volume due to injury, illness, or other health problems during the past week?

- No reduction (0)
- To a minor extent (6)
- To a moderate extent (13)
- To a major extent (19)
- Cannot participate at all (25)

Q10c: Performance

To what extent has injury, illness or other health problems affecting your performance in training during the past week?

- No effect (0)
- To a minor extent (6)
- To a moderate extent (13)
- To a major extent (19)
- Cannot participate at all (25)

Q10d: Symptoms

To what extent have you experienced symptoms/health complaints during the past week?

- No symptoms/health complaints (0)
- To a mild extent (8)
- To a moderate extent (17)
- To a severe extent (25)

Skip Logic: If Q10a, Q10b, Q10c and Q10d = 0 then skip to Question 17

If you have several illnesses or injury problems, please refer to the one that has been your worst problem this week.

Question 11:

Is the health problem referred to in the four questions above an injury or an illness?

- Injury
- Illness
- No injury, illness, or health problem

Skip Logic:

If Q11 = Injury continues to Question 12a

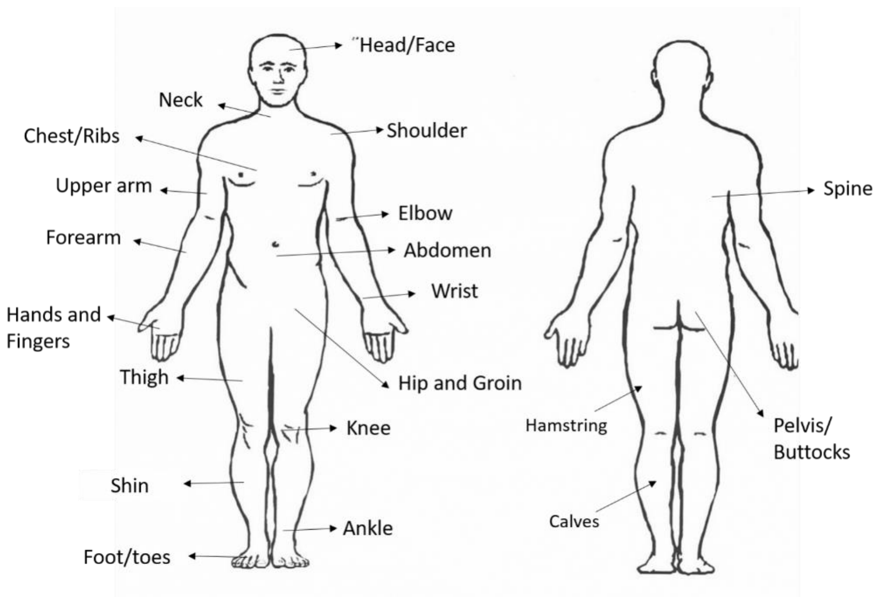
If Q11 = Illness, then skip to Question 13a

If Q11 = No injury, illness or health problem then skip to Question 17

INJURY

Question 12a:

Please select the box that best describes the location of your injury. If the injury involves several locations, please select the main areas. If you have multiple injuries, you will have a chance to register other problems at the end of the questionnaire.



Question 12b:

Please indicate whether the injury location is on the right or left of your body?

- Right (1)
- Left (2)
- Both Sides (4)
- Other, please specify: ____

Question 12c:

If you are aware of the type/nature of the injury you have sustained, please indicate below (if you are unsure, please tick 'I don't know).

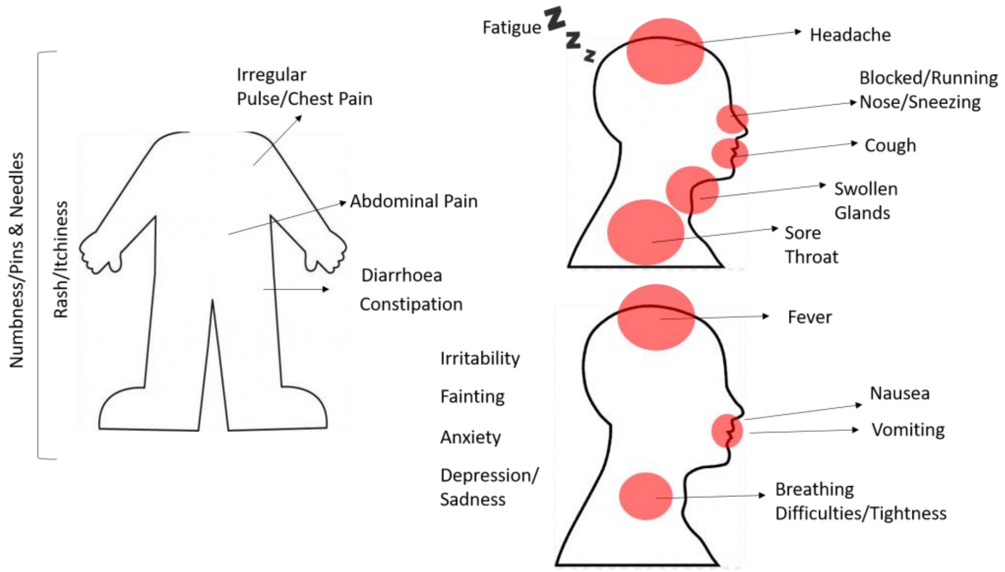
- Concussion (regardless of loss of consciousness)
- Fracture (traumatic)
- Stress fracture (overuse)
- Other bone injuries
- Dislocation
- Tendon rupture
- Ligament rupture
- Sprain (injury of joint and/or ligaments)
- Lesion of meniscus or cartilage
- Strain/muscle rupture/tear
- Bruise
- Laceration/abrasion/skin lesion
- Dental Injury/broken tooth
- Other, please specify: ____
- I don't know

<u>Now skip to Question 14</u>

ILLNESS

Question 13a:

Please select the boxes corresponding to the major symptoms you have experienced during the past 7 days. You may select several alternatives; however, in the case that you have several unrelated illnesses please register them at the end of the questionnaire.



Question 13b:

If the symptoms experienced are not listed, please describe your symptoms below (including any diagnosis from medical professionals).

____

____

____

HEALTH PROBLEM IMPACT

Question 14:

Please state the number of days over the past 7-day period that you have had to completely miss training or competition due to this problem? (You may indicate half days as well – use .5 to indicate).

Question 15:

Is this the first time you have registered this problem through this monitoring system?

- Yes, this is the first time
- No, I have reported the same problem in one of the previous two weeks
- No, I have reported the same problem previously, but it was more than two weeks ago

Question 16:

Have you experienced any other illnesses, injuries, or other health problems during the past 7 days?

- Yes, please provide a summary (e.g., injury or illness, area of body affected, performance/training effect, including any diagnosis from medical professionals). ____
- No other health problems to report

SLEEP

The following questions relate to your usual sleep habits during the past week only. The first set of questions asks about your usual sleep habits on days that you train, the second set asks about your usual sleep habits on rest days.

Question 17

Q17a: On training days during the past week, what time have you usually gone to bed at night? Please report using the 24hr clock (00:00, e.g., 22:00 for 10 pm).

Q17b: On training days during the past week, what time have you usually got out of bed in the morning? Please report using the 24hr clock (00:00, e.g., 07:00 for 7 am).

Q17c: On rest days during the past week, what time have you usually gone to bed at night? Please report using the 24hr clock (00:00, e.g., 22:00 for 10 pm).

Q17d: On rest days during the past week, what time have you usually got out of bed in the morning? Please report using the 24hr clock (00:00, e.g., 07:00 for 7 am).

Question 18:

Q18a: On training days during the past week, how many hours of actual sleep did you get at night (this may be different than the number of hours you spend in bed)? Please report using the format hh:mm (e.g., 8 hour 30 minutes = 08:30).

Q18b: On rest days during the past week, how many hours of actual sleep did you get at night (this may be different from the number of hours you spend in bed)? Please report using the format hh: mm (e.g., 8 hour 30 minutes = 08:30).

Question 19:

How would you rate your sleep quality overall? Please choose one which is closest to your sleep quality over the past week.

- Very Good (1)
- Fairly Good (2)

- Fairly Bad (3)
- Very Bad (4)

Question 20:

Please indicate how often you had trouble sleeping because of you…

	Not during the past week (1)	Less than once a week (2)	Once or twice a week (3)	Three or more times a week (4)
…cannot get to sleep within 30 minutes. (1)	○	○	○	○
…wake up in the middle of the night or early morning. (2)	○	○	○	○

Question 21a

How many days over the past week have you had a nap during the daytime?

- 0, 1, 2, 3, 4, 5, 6, 7

Question 21b:

On the days where you napped, on average how many hours would you nap? (> = greater than, < = less than)

- Less than 0.5 hour
- > 0.5 hours but < 1 hour
- > 1 hour but < 1.5 hours
- > 1.5 but < 2 hours
- > 2 but < 2.5 hours
- > 2.5 but < 3 hours
- > 3 but < 3.5 hours
- > 3.5 but < 4 hours
- More than 4 hours

WELLBEING:

Question 22:

Please indicate for each of the five statements which are closest to how you have been feeling over the past week.

	At no time	Some of the time	Less than half the time	More than half the time	Most of the time	All the time
I have felt cheerful and in good spirits	○	○	○	○	○	○
I have felt calm and relaxed	○	○	○	○	○	○
I have felt active and vigorous	○	○	○	○	○	○
I woke up feeling fresh and rested	○	○	○	○	○	○
My daily life has been filled with things that interest me	○	○	○	○	○	○

Question 23:

The questions in this scale ask you about your feelings and thoughts during the past week. In each case, please indicate how often you felt/thought a certain way in the past week.

	Never	Almost Never	Sometimes	Fairly Often	Very Often
How often have you felt that you were unable to control the important things in your life?	○	○	○	○	○
How often have you felt confident about your ability to handle your personal problems?	○	○	○	○	○
How often have you felt that things were going your way?	○	○	○	○	○
How often have you felt difficulties were piling up so high that you could not overcome them?	○	○	○	○	○

Appendices 3.2: Sample mean AMQ values across all time points (T)

	Availability (health problem; HP)		Availability (modification; mod)	
	Below 90% (HP)	Above 90% (HP)	Below 90% (mod)	Above 90% (mod)
Availability (HP) (%)	77	95	75	87
Availability (Modifications) (%)	45	48	43	47
T1 Pool Access (%)	100	100	100	100
T2 Pool Access (%)	45	43	40	47
T3 Pool Access (%)	50	27	47	40
T4 Pool Access (%)	100	93	100	97
T5 Pool Access (%)	92	83	87	90
T1 Full Participation without Health problems (%)	72	94	72	83
T1 Full Participation with Health Problem (%)	11	3	11	7
T1 Severity Score of Health problems (0-100)	45.4	10.9	43.9	28.9
T1 Sum Hours (hh: mm: ss)	19:48:15	21:27:26	20:15:17	20:24:20
T1 Sport Specific Training Hours (hh: mm: ss)	14:05:28	15:19:15	14:07:28	14:41:21

T1 Other Training Hours (hh: mm: ss)	03:03:34	03:19:31	03:20:17	03:03:11
T1 Competition Hours (hh: mm: ss)	02:39:14	02:48:40	02:47:32	02:39:47
T1 Swimming Distance (km)	37.2	50.0	34.2	45.1
T1 Days Competed	0.8	0.8	0.8	0.8
T1 Number of Races	1.8	2.1	1.9	1.9
T1 Perceived Readiness to Train (1-6)	3.8	3.9	3.6	4.0
T1 Perceived Recovery (1-10)	6.9	6.2	6.4	6.8
T1 Perceived Exertion (1-10)	5.6	7.0	5.3	6.4
T1 Prevalence of Injury (%)	7	3	7	5
T1 Prevalence of Illness (%)	21	3	21	12
T1 Prevalence of Health Problem (%)	28	6	28	17
T1 Completion Rate (%)	84	91	75	92
T1 Days Missed	0.3	0.0	0.4	0.1
T1 Train Day Hours Sleep (hh: mm: ss)	06:59:47	07:10:37	07:02:05	07:04:02
T1 Rest Day Hours Sleep (hh: mm: ss)	09:12:18	10:04:33	09:05:27	09:41:51
T1 Absence of Sleep Latency (%)	36	85	10	73

T1 Prevalence of Bad Sleep (%)	14	0	26	1
T1 Absence of Sleep Disturbance (%)	32	71	15	60
T1 Days Napping	2.4	1.2	2.9	1.6
T1 Nap Length (hh: mm: ss)	01:22:53	00:54:30	01:24:00	01:08:08
T1 Sleep Total in 24 Hour (hh: mm: ss)	07:52:43	07:50:28	08:02:25	07:46:45
T1 Bedtime (Training Days) (hh: mm: ss)	21:58:00	21:52:25	22:10:05	21:49:10
T1 Wake Time (Training Days) (hh: mm: ss)	05:33:42	05:07:11	05:57:08	05:08:44
T1 Bedtime (Rest Days) (hh: mm: ss)	22:16:50	22:03:57	22:22:52	22:07:22
T1 Wake Time (Rest Days) (hh: mm: ss)	08:52:51	09:09:58	09:04:55	08:55:22
T1 Perceived Wellbeing Value (0-25)	18.4	18.1	16.5	19.2
T1 Perceived Stress Value (0-16)	3.4	3.6	4.6	2.9
T2 Full Participation without Health Problem (%)	82	90	85	84
T2 Full Participation with Health Problem (%)	10	2	5	9
T2 Severity Score of Health problems (0-100)	25.4	19.6	26.4	22.0
T2 Sum Hours (hh: mm: ss)	15:45:26	18:15:38	15:46:51	16:59:50
T2 Sport Specific Training Hours (hh: mm: ss)	07:29:37	10:06:22	07:12:09	08:56:44

T2 Other Training Hours (hh: mm: ss)	07:14:08	06:28:49	07:05:51	06:55:37
T2 Competition Hours (hh: mm: ss)	01:01:41	01:40:27	01:28:51	01:07:29
T2 Swimming Distance (km)	21.4	29.9	20.2	26.2
T2 Days Competed	0.3	0.4	0.4	0.3
T2 Number of Races	0.6	1.3	0.8	0.8
T2 Perceived Readiness to Train (1-6)	3.8	3.6	3.6	3.8
T2 Perceived Recovery (1-10)	7.0	5.8	6.5	6.6
T2 Perceived Exertion (1-10)	5.7	6.1	5.3	6.1
T2 Perceived Motivation (1-10)	3.5	2.7	3.2	3.2
T2 Prevalence of Injury (%)	12	0	13	6
T2 Prevalence of Illness (%)	6	5	2	8
T2 Prevalence of Health Problem (%)	18	5	15	14
T2 Completion Rate (%)	68	65	63	69
T2 Days Missed	0.0	0.0	0.0	0.0
T2 Train Day Hours Sleep (hh: mm: ss)	08:17:48	08:03:16	08:31:43	08:03:35
T2 Rest Day Hours Sleep (hh: mm: ss)	09:28:36	09:34:22	09:30:09	09:30:43

T2 Absence of Sleep Disturbance (%)	31	69	22	55
T2 Prevalence of Bad Sleep (%)	2	2	3	1
T2 Absence of Sleep Latency (%)	44	90	16	81
T2 Days Napping	1.3	0.6	1.4	0.8
T2 Nap Length (hh: mm: ss)	00:50:19	00:34:25	00:50:41	00:42:11
T2 Sleep Total in 24 Hour (hh: mm: ss)	08:45:59	08:23:49	09:01:13	08:27:16
T2 Bedtime (Training Days) (hh: mm: ss)	22:37:08	22:37:05	22:47:04	22:32:08
T2 Wake Time (Training Days) (hh: mm: ss)	07:32:54	06:51:16	07:56:26	07:00:19
T2 Bedtime (Rest Days) (hh: mm: ss)	22:43:25	22:48:44	22:49:47	22:42:53
T2 Wake Time (Rest Days) (hh: mm: ss)	09:17:22	09:15:30	09:23:39	09:13:18
T2 Perceived Wellbeing Value (0-25)	18.4	16.7	17.3	18.1
T2 Perceived Stress Value (0-16)	3.6	4.7	4.8	3.5
T3 Full Participation without Health problems (%)	84	98	91	88
T3 Full Participation with Health Problem (%)	12	0	0	12
T3 Severity Score of Health problems (0-100)	16.6	9.2	24.3	9.0
T3 Sum Hours (hh: mm: ss)	11:14:54	16:54:31	09:03:15	15:10:32

T3 Sport Specific Training Hours (hh: mm: ss)	05:05:22	07:41:18	04:12:07	06:49:58
T3 Other Training Hours (hh: mm: ss)	06:09:32	09:13:12	04:51:09	08:20:34
T3 Competition Hours (hh: mm: ss)	00:00:00	00:00:00	00:00:00	00:00:00
T3 Swimming Distance (km)	12.2	20.6	9.4	17.8
T3 Days Competed	0.0	0.0	0.0	0.0
T3 Number of Races	0.0	0.0	0.0	0.0
T3 Perceived Readiness to Train (1-6)	3.6	4.2	3.2	4.1
T3 Perceived Recovery (1-10)	6.9	6.7	6.6	7.0
T3 Perceived Exertion (1-10)	4.9	5.3	4.3	5.4
T3 Perceived Motivation (1-10)	3.4	4.3	3.0	4.1
T3 Prevalence of Injury (%)	15	0	7	12
T3 Prevalence of Illness (%)	1	2	2	1
T3 Prevalence of Health Problem (%)	16	2	9	12
T3 Completion Rate (%)	58	58	55	59
T3 Days Missed	0.0	0.0	0.1	0.0
T3 Train Day Hours Sleep (hh: mm: ss)	08:46:11	08:09:39	09:04:19	08:18:51

T3 Rest Day Hours Sleep (hh: mm: ss)	09:11:23	09:30:02	09:09:15	09:21:46
T3 Absence of Sleep Latency (%)	43	98	15	84
T3 Prevalence of Bad Sleep (%)	6	0	11	0
T3 Absence of Sleep Disturbance (%)	22	97	17	62
T3 Days Napping	0.7	0.4	0.5	0.6
T3 Nap Length (hh: mm: ss)	00:38:37	00:31:37	00:40:42	00:34:04
T3 Sleep Total in 24 Hour (hh: mm: ss)	08:57:52	08:26:20	09:12:36	08:34:44
T3 Bedtime (Training Days) (hh: mm: ss)	22:58:23	22:58:34	23:14:33	22:50:24
T3 Wake Time (Training Days) (hh: mm: ss)	08:46:32	07:21:29	09:16:54	07:48:49
T3 Bedtime (Rest Days) (hh: mm: ss)	23:12:37	23:23:50	23:33:51	23:07:37
T3 Wake Time (Rest Days) (hh: mm: ss)	09:34:58	09:28:52	09:37:49	09:30:30
T3 Perceived Wellbeing Value (0-25)	18.0	18.5	15.7	19.4
T3 Perceived Stress Value (0-16)	3.7	4.1	5.1	3.3
T4 Full Participation without Health problems (%)	81	100	66	98
T4 Full Participation with Health Problem (%)	8	0	12	2
T4 Severity Score of Health problems (0-100)	17.6	0.0	23.4	6.0

T4 Sum Hours (hh: mm: ss)	14:29:55	19:13:12	13:26:48	17:23:07
T4 Sport Specific Training Hours (hh: mm: ss)	11:16:07	14:21:00	10:06:12	13:23:31
T4 Other Training Hours (hh: mm: ss)	03:04:53	04:33:48	03:15:12	03:44:11
T4 Competition Hours (hh: mm: ss)	00:08:56	00:18:24	00:05:24	00:15:26
T4 Swimming Distance (km)	26.8	47.4	22.8	39.1
T4 Days Competed	0.1	0.1	0.0	0.1
T4 Number of Races	0.2	0.5	0.1	0.4
T4 Perceived Readiness to Train (1-6)	3.5	4.2	3.5	3.8
T4 Perceived Recovery (1-10)	6.2	5.7	6.7	5.8
T4 Perceived Exertion (1-10)	4.8	5.9	4.8	5.4
T4 Perceived Motivation (1-10)	3.6	4.6	3.5	4.1
T4 Prevalence of Injury (%)	12	0	22	1
T4 Prevalence of Illness (%)	18	0	13	12
T4 Prevalence of Health Problem (%)	29	0	34	12
T4 Completion Rate (%)	50	51	51	50
T4 Days Missed	0.3	0.0	0.5	0.0

T4 Train Day Hours Sleep (hh: mm: ss)	07:49:17	07:41:36	08:21:00	07:29:35
T4 Rest Day Hours Sleep (hh: mm: ss)	09:04:16	09:18:54	09:07:36	09:09:55
T4of Absence of Sleep Latency (%)	40	100	25	78
T4 Prevalence of Bad Sleep (%)	2	0	3	1
T4 Absence of Sleep Disturbance (%)	36	96	2	83
T4 Days Napping	1.3	0.6	1.4	0.9
T4 Nap Length (hh: mm: ss)	00:53:40	00:36:36	00:40:15	00:51:50
T4 Sleep Total in 24 Hours (hh: mm: ss)	08:17:05	08:02:57	08:46:02	07:55:33
T4 Bedtime (Training Days) (hh: mm: ss)	22:16:46	22:30:42	22:03:36	22:30:19
T4 Wake Time (Training Days) (hh: mm: ss)	06:25:15	06:16:48	06:24:42	06:21:18
T4 Bedtime (Rest Days) (hh: mm: ss)	22:41:40	23:09:48	22:33:18	22:59:55
T4 Wake Time (Rest Days) (hh: mm: ss)	08:25:51	09:06:00	08:09:18	08:54:12
T4 Perceived Wellbeing Value (0-25)	17.9	19.0	17.0	18.9
T4 Perceived Stress Value (0-16)	4.3	3.6	5.1	3.5
T5 Full Participation without Health Problem (%)	66	92	63	81
T5 Full Participation with Health Problem (%)	20	2	21	11

T5 Severity Score of Health problems (0-100)	22.3	27.5	18.7	26.7
T5 Sum Hours (hh: mm: ss)	15:58:03	19:40:50	14:27:29	18:34:43
T5 Sport Specific Training Hours (hh: mm: ss)	11:07:02	13:42:48	09:37:51	13:09:30
T5 Other Training Hours (hh: mm: ss)	03:32:02	05:12:44	03:30:03	04:23:22
T5 Competition Hours (hh: mm: ss)	01:18:59	00:45:19	01:19:35	01:01:51
T5 Swimming Distance (km)	30.3	39.7	27.3	36.5
T5 Days Competed	0.4	0.3	0.3	0.4
T5 Number of Races	1.0	0.5	0.7	0.9
T5 Perceived Readiness to Train (1-6)	3.5	4.1	3.3	3.9
T5 Perceived Recovery (1-10)	6.7	6.1	6.9	6.4
T5 Perceived Exertion (1-10)	5.3	5.4	4.9	5.5
T5 Perceived Motivation (1-10)	3.8	4.5	3.7	4.2
T5 Prevalence of Injury (%)	20	4	25	9
T5 Prevalence of Illness (%)	14	4	12	10
T5 Prevalence of Health Problem (%)	34	8	38	19
T5 Completion Rate (%)	68	91	65	81

T5 Days Missed	0.1	0.0	0.0	0.1
T5 Train Day Hours Sleep (hh: mm: ss)	08:08:32	07:51:37	08:41:23	07:43:39
T5 Rest Day Hours Sleep (hh: mm: ss)	09:16:23	09:31:33	09:28:03	09:18:08
T5 Absence of Sleep Latency (%)	43	93	18	80
T5 Prevalence of Bad Sleep (%)	11	0	13	5
T5 Absence of Sleep Disturbance (%)	26	86	25	57
T5 Days Napping	1.1	0.7	0.8	1.0
T5 Nap Length (hh: mm: ss)	00:46:38	00:32:46	00:35:11	00:45:26
T5 Sleep Total in 24 Hours (hh: mm: ss)	08:33:40	08:11:36	09:01:15	08:08:50
T5 Bedtime (Training Days) (hh: mm: ss)	22:07:25	22:38:47	22:20:06	22:16:46
T5 Wake Time (Training Days) (hh: mm: ss)	07:05:30	06:25:38	07:29:48	06:33:25
T5 Bedtime (Rest Days) (hh: mm: ss)	22:17:29	23:14:28	22:34:47	22:37:20
T5 Wake Time (Rest Days) (hh: mm: ss)	09:05:34	09:27:57	08:50:29	09:24:18
T5 Perceived Wellbeing Value (0-25)	17.7	18.2	16.4	18.6
T5 Perceived Stress Value (0-16)	4.3	4.0	5.5	3.6

Appendices 4.1: Definitions of psychosocial variables

Acceptance of Team Goals (Callow et al., 2009)**:** Coaches and support staff encourages athletes to be team players and work together for the same goal.

Active Coping (Hill et al., 2019a)**:** Recognises the proactive, self-regulated deployment of coping mechanisms.

Adverse Response to Failure (Hill et al., 2019b): Responding adversely to failure.

Agreeableness (Gosling et al., 2003a)**:** Being kind, cooperative and, considerate.

Amotivation (Pelletier et al., 2013b)**:** None regulation of motivation and a lack of intention to act.

Appropriate Role Model (Callow et al., 2009)**:** Coaches and supports staff lead by and set a good example.

Autonomy (Ng et al., 2011a)**:** The perception that one can make decisions, has choices, and participates willingly.

Autonomy Importance (Glendinning, 2018a): Whether it is important for someone to feel a sense of autonomy.

Autonomy Support (Markland & Tobin, 2010a): Where there is choice, explanation and rationale, and acknowledgement of negative feelings in the environment.

Career Turning Point (Hardy et al., 2017): Experience of a career turning point increasing motivation, focus or determination to succeed.

Clinical Indicators (Hill et al., 2019b): Mental health constructs that impact upon the talent development process and swimmer wellbeing.

Closeness (Jowett & Ntoumanis, 2004a): Feeling emotionally close with one other in the coach-swimmer relationship.

Commitment (Jowett & Ntoumanis, 2004b): The intention to maintain an interpersonal relationship.

Commitment to Training (Hardy et al., 2017): Investing significant effort into attending and completing training sessions.

Competence (Ng et al., 2011b): The perception that one can control the outcome and experience mastery.

Competence Importance (Glendinning, 2018b): Whether someone needs to experience mastery and control an outcome.

Complementarity (Jowett & Ntoumanis, 2004b): Reflects cooperative interactions, especially during training.

Comprehensibility (Glendinning, 2018b): The perception that one's life and future are understandable and predictable.

Conscientiousness (Gosling et al., 2003b): Being careful and diligent with a desire to complete tasks to a high standard.

Contingent Reward (Callow et al., 2009): Coaches and support staff provide positive reinforcement in return for appropriate behaviour and performance.

Counterphobic Attitude (Hardy et al., 2017): Thriving on or being drawn to intense emotions elicited in high-level competition.

Developmental Feedback (Wagstaff et al., 2017b)**:** Coaches provide direction for self-awareness, reflection, and performance improvement.

Difficulty with Emotional Expression (Barlow et al., 2013)**:** Experiencing difficulty with understanding and describing emotions.

Dismissing Attachment Style Rating (Bartholomew & Horowitz, 1991a): Positive view of the self with a negative view of others.

Effective Questioning (Wagstaff et al., 2017a): The extent to which coaches engage in asking questions that encourage thought and reflection.

Emotional Stability (Gosling et al., 2003b): Being able to remain stable and balanced when dealing with challenging situations and handling adversity.

Emotional Support (Freeman et al., 2011a): The extent to which someone would be there for comfort and security.

Emotional Support from social media (McCloskey et al., 2015a)**:** The extent to which emotional support can be accessed through social media.

Empathic Thinking (Baron-Cohen et al., 2001b)**:** Understanding and responding to another individual's mental state.

Environment of Expectation and Achievement (Hardy et al., 2017): Exposed to an aspirational environment, or culture of achievement, during developmental years.

Esteem Support (Freeman et al., 2011b): The extent to which someone would encourage one's sense of competence or self-esteem.

External Regulation (Pelletier et al., 2013a): Performing behaviour because of external rewards/ demands.

Extraversion (Gosling et al., 2003b): Enjoying human interactions and obtaining gratitude from outside of oneself.

Fearful Attachment Style Rating (Bartholomew & Horowitz, 1991b): Negative view of the self with a negative view of others.

Goal Setting (Wagstaff et al., 2017a): The extent to which coaches provide support to help attain one's goals.

Grandiose Narcissism (Ames et al., 2006)**:** Grandiose sense of self-importance and desire for admiration.

High-performance Expectations (Callow et al., 2009): Coaches and support staff express expectations for excellence, quality and/or high-performance.

Highly Competitive Environment (Hardy et al., 2017): Being exposed to a highly competitive environment in sports and or other family life from a young age.

Identified Regulation (Pelletier et al., 2013a): Performing behaviour because it is a goal that important to oneself.

Imagery and Active Preparation (Hill et al., 2019b): Effective and controllable imagery in both skill refinement and the management of arousal.

Individual Consideration (Wagstaff et al., 2017a): The extent to which coaches show respect and concern for one's feelings and needs.

Informational Support (Freeman et al., 2011b): The extent to which someone would provide support or guidance.

Inspirational Motivation (Callow et al., 2009): Coaches and support staff develop, articulate, and inspire others with their vision for the future.

Instrumental Support from social media (McCloskey et al., 2015b): The extent to which support through information can be accessed through social media.

Negative Instrumental Support from social media (McCloskey et al., 2015b): The extent to which social media provides negative support.

Integrated Regulation (Pelletier et al., 2013a): Performing behaviour because it is a goal that is in line with one's values and principles.

Intellectual Stimulation (Callow et al., 2009): Coaches and support staff challenge individuals to re-examine their assumptions about work.

Intrinsic Motivation (Pelletier et al., 2013a): Performing behaviour because of pure interest, curiosity, challenge, or enjoyment.

Introjected Regulation (Pelletier et al., 2013a): Performing behaviour because it is contingent on other things e.g., self-esteem or guilt, not because one has accepted behaviour regulations as their own.

Involvement (Markland & Tobin, 2010b): Where there is respect, and one feels cared for included and secure in the environment.

Manageability (Glendinning, 2018b): The perception that one's life is manageable and within their control and that one has the skills to do this.

Mastery Focus (Hardy et al., 2017): Setting goals where performance is judged by a self-reference or objective standard.

Mastery Focused Environment (Hardy et al., 2017): A family value of mastery.

Meaningfulness (Glendinning, 2018b): The perception that things in life and satisfying and interesting and there is good reason to care about what happens.

Mental Toughness (Gucciardi et al., 2015)**:** To consistently produce high levels of objective performance despite everyday challenges/ stressors as well as significant adversities.

Motivational Feedback (Wagstaff et al., 2017a): The extent to which coaches praise desirable behaviours.

Need to Avoid Failure (Hardy et al., 2017): A deep-seated desire not to lose.

Need to Succeed (Hardy et al., 2017): A deep-seated desire to win/ succeed.

Observation (Wagstaff et al., 2017a): The extent to which coaches closely observe and engage in performance analysis of an individual.

Obsessiveness (Hardy et al., 2017): An extreme internal pressure to engage in certain activities or behaviours.

Open to New Experiences (Gosling et al., 2003b): Being open-minded and open to new things.

Organisational Support (Eisenberger et al., 1986)**:** The belief concerning the extent to which the National Governing Body values one's contributions and cares about their wellbeing

Outcome Focus (Hardy et al., 2017): Setting goals where performance is judged by winning or performing better than other people.

Outcome Focused Environment (Hardy et al., 2017): A family value of an outcome focus.

Perceived Support from Social Media (McCloskey et al., 2015b): The perception of support is available from social media.

Perfectionistic Concerns (Stoeber et al., 2006a)**:** An overly critical evaluation of one's self over mistakes.

Perfectionistic Strivings (Stoeber et al., 2006b)**:** Holding oneself to high standards and striving for perfection.

Perfectionistic Tendencies (Hill et al., 2019b): Combination of perfectionism, anxiety, fear of failure and the obsessive component of passion.

Positive Critical Life Event (Hardy et al., 2017): "Finding" one's sport, "finding" a significant (sporting) other or experiencing an inspirational (sporting) moment.

Preoccupied Attachment Style Rating (Bartholomew & Horowitz, 1991b): Negative view of the self with a positive view of others.

Psychopathy traits (Levenson et al., 1995)**:** Continuous antisocial behaviour, impulsiveness, lack of empathy and remorse.

Relatedness (Ng et al., 2011b): The perception that one is connected to others.

Relatedness Importance (Glendinning, 2018b): Whether someone needs to interact with and feel connected to others.

Relationality (Glendinning, 2018b): The extent to which one feels that they can rely on and understand the behaviour of the people around them.

Relative Importance of Sport (Hardy et al., 2017): "Finding" one's sport, "finding" a significant (sporting) other or experiencing an inspirational (sporting) moment.

Responsiveness (Reis et al., 2008): The perception that coaches are responsive to one's needs, feelings, and concerns.

Ruthlessness (Hardy et al., 2017): Willingness to be disliked in an attempt to achieve targets in sport.

Ruthlessness (Hardy et al., 2017): Willingness to put oneself first in an attempt to achieve targets in sport.

Secure Attachment Style Rating (Bartholomew & Horowitz, 1991b): Positive view of the self with a positive view of others.

Seeking and Using Social Support (Hill et al., 2019b): The extent to which there are effective support networks to facilitate talent development.

Self Esteem (Rosenberg, 2015): Belief in one's worth or abilities.

Self-Directed Control and Management (Hill et al., 2019b): The extent to which one can self-control and regulate.

Socially Prescribed Perfectionism (Cox et al., 2002)**:** A belief that others expect perfection.

Strong Work Ethic (Hardy et al., 2017): Being exposed to a strong work ethic from a young age.

Structure (Markland & Tobin, 2010b): Where there is an optimal challenge and positive performance feedback in the environment.

Systematic Thinking (Baron-Cohen et al., 2001a): A drive towards analysing and constructing systems.

Tangible Support (Freeman et al., 2011b): The extent to which someone would provide instrumental assistance.

Total Preparation for Competition (Hardy et al., 2017): Perception that one could not have done any more to be better prepared for high-pressure competition.

Vulnerable Narcissism (Hendin & Cheek, 1997): Presents as defensive, avoidant, and hypersensitive to criticism.

Appendices 4.2: Descriptive statistics for the ADFS variables

	Average	SD	Min	Max
Life Experience				
Environment of Expectation	7.3	1.5	5	10
Strong Work Ethic	9.1	1.1	7	10
High Competitive Environment	5.7	2.2	2	10
Outcome Focus	6.2	2.3	2	10
Mastery Focus	7.8	1.7	4	10
Career Turning Point	8.5	1.5	6	10
Positive Critical Life Event	8.6	1.3	7	10
Personality				
Difficulty With Emotion	5.6	1.9	3	8
Counterphobic Attitude	6.4	1.3	4	8
Need to Avoid Failure	5.1	2.1	2	10
Need to Succeed	6.9	1.6	3	9
Ruthlessness	6.8	2.1	3	10
Selfishness	7.3	1.8	3	10
Perfectionistic Concerns (Training)	6.7	1.6	4	9
Perfectionistic Concerns (Competition)	7.2	1.7	5	10

Perfectionistic Strivings	7.8	1.2	6	10
Socially Prescribed Perfectionism	6.0	1.7	3	8
Obsessiveness	6.9	2.4	2	10
Grandiose Narcissism	5.8	1.7	4	9
Vulnerable Narcissism	4.8	1.9	2	8
ASD Empathy	5.0	1.3	2	7
ASD Systemising	6.1	1.4	3	8
Psychopathy PPI	4.6	1.5	2	7
Psychopathy Levensons	3.9	1.1	2	6
Extraversion	6.1	2.4	2	10
Agreeableness	7.4	1.4	6	9
Conscientiousness	8.6	1.8	5	10
Emotional Stability	7.1	2.4	2	10
Open New Experiences	7.4	1.4	5	10
Training Behaviours				
Outcome Focus	7.6	1.9	4	10
Mastery Focus	9.5	0.9	8	10
Total Preparation (for training & competition)	7.5	1.4	6	10
Commitment to Training	7.8	2.4	3	10
Relative Importance of Sport	6.8	2.1	4	10

Note: Minimum score is 2, and the maximum score is 10.

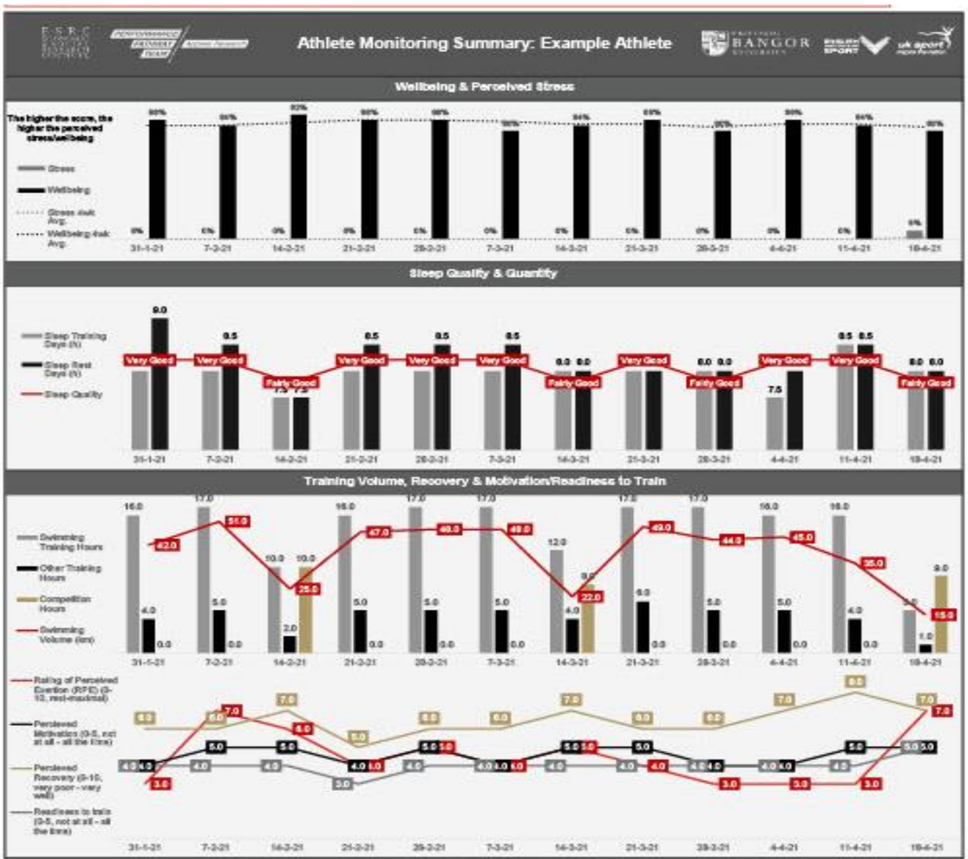
Appendices 4.3: Descriptive statistics for the CDFS variables

Variables	Mean	SD	Min	Max

Difficulty With Emotion	6.7	1.3	4.0	8.0
Counterphobic Attitude	4.4	1.0	2.0	5.0
Need to Avoid Failure	5.5	0.9	4.0	7.0
Need to Succeed	3.0	0.9	2.0	5.0
Ruthlessness	5.4	1.0	4.0	7.0
Selfishness	6.1	2.0	2.0	9.0
Perfectionistic Concerns Training	2.7	0.9	2.0	5.0
Perfectionistic Concerns Competition	6.9	1.7	4.0	9.0
Perfectionistic Strivings	4.5	2.2	2.0	8.0
Socially Prescribed Perfectionism	4.9	1.7	2.0	8.0
Obsessiveness	6.6	2.4	4.0	11.0
Grandiose Narcissism	6.8	1.6	4.0	10.0
Vulnerable Narcissism	8.0	1.7	5.0	10.0
ASD Empathy	6.8	1.2	5.0	9.0
ASD Systemising	5.1	1.4	3.0	8.0
Psychopathy PPI	5.7	1.3	4.0	8.0
Psychopathy Levensons	7.2	1.7	4.0	10.0
Extraversion	7.8	1.4	5.0	10.0
Agreeableness	5.1	1.8	2.0	8.0
Conscientiousness	6.9	1.5	5.0	10.0
Emotional Stability	6.6	0.9	5.0	8.0
Open New Experiences	6.2	0.9	5.0	8.0

Appendices 4.4: Example swimmer AMQ feedback

An individualised feedback form, similar to the example provided below, was produced and sent weekly to each athlete (Swimming n = 16, Rowing n = 13) for 78 weeks (Swimming) and 28 weeks (Rowing). The example form below is specific to swimming, a similar report with Rowing specific volume parameters was created for Rowing athletes. An individualised feedback form was also sent to the respective coaches of swimmers that consented to this data being shared (Swimming n = 15).



Training Details

	2021-01-31	2021-02-07	2021-02-14	2021-02-21	2021-02-28	2021-03-07	2021-03-14	2021-03-21	2021-03-28	2021-04-04	2021-04-11	2021-04-18
Types/Examples of Training	Swim, S&C, Yoga	Swim, S&C, Pilates	Swim, S&C, Yoga	Swim, S&C, Yoga	Swim, S&C, Landbased	Swim, S&C, Landbased	Swim, S&C, Landbased	Swim, S&C, Landbased	Swim, S&C, Landbased	Swim, S&C, Landbased	Swim, S&C, Landbased	Swim, S&C, Landbased
Sleep												
Cannot get to sleep?	Not during the past week	Not during the past week	Once or twice a week	Not during the past week	Not during the past week	Not during the past week	Once or twice a week	Not during the past week	Less than once a week	Once or twice a week	Less than once a week	Once or twice a week
Wake up during the night?	Not during the past week	Not during the past week	Not during the past week	Less than once a week	Less than once a week	Less than once a week	Less than once a week	Less than once a week	Not during the past week	Not during the past week	Not during the past week	Once or twice a week
Days Napping	0	0	1	0	0	0	0	0	1	0	0	0
Average Nap Length			Greater than 0.5 but less than 1 hour						Greater than 0.5 but less than 1 hour			
Injury & Illness												
Training Days Missed	0.5	0	0	0	0	0	0	0	0	0	0	0
Injury	Upper Body											
Illness												
Competition Details												
Days of Competitions	0	0	3	0	0	0	3	0	0	0	0	4
Number of Races / Competitions	0	0	9	0	0	0	8	0	0	0	0	7

Appendices 4.5: Example coach/group AMQ feedback

A group feedback form, similar to the example provided below, was produced and sent weekly to the performance director, medical lead and/or head coach (recipients differed depending on the request of the sport) of the squad. Note that the example form below is specific to swimming, a similar report with Rowing specific volume parameters was created for Rowing athletes.

Athlete Monitoring Questionnaire: Group Weekly Summary

Week Commencing 2021-02-07

Athlete	Training: Swimming Training Hours	Other Training Hours (e.g. S&C)	Examples of current training	Competition Hours	Volume (km)	Days Competing	Readiness	Motivation	Recovery	RPE	Training Days Missed	Sleep: Sleep Quality	Total Daily Sleep (h:mm)	Night Sleep (Training Day; h:mm)	Night Sleep (Rest Day; h:mm)	Napping Days	Napping Duration	Health: Well Being	Perceived Stress	Injury	Illness
Athlete 1	0	11	Weights Spinning	0	0	0	4	4	7	6	0	Very Good	9:08	9:00	10:00	0		80%	6%		
Athlete 2	17	5	Swim, gym, dryland	0	51	0	4	5	6	7	0	Very Good	8:04	8:00	8:30	0		84%			
Athlete 3	20	5	0	0	55	0	3	5	4	7	0	Very Good	8:21	8:00	10:30	0		60%	13%		
Athlete 4	18	4	Aerobic, Vo2, short rest, threshold, speed	0	45	0	5	5	8	7	0	Fairly Good	8:57	8:30	10:00	1	Greater than 1.5 but less than 2 hours	80%	25%		
Athlete 5	14	2	Swimming weights	0	33	0	4	4	6	3	0	Fairly Good	8:30	8:00	8:00	2	Greater than 1.5 but less than 2 hours	80%	25%		
Athlete 6	18	2	0	0	39	0	4	4	8	4	0	Fairly Good	8:34	8:30	9:00	0		72%	25%		
Athlete 7	0	0		0	0	0					0					0					
Athlete 8	0	0		0	0	0					0					0					
Athlete 9	18	4	Aerobic, vo2, race pace	0	53	0	4	4	8	8	0	Fairly Good	8:17	8:00	10:00	0		64%	50%		
Athlete 10	17	3	Swiming, gym	0	50	0	4	5	5	8	0	Fairly Good	9:04	9:00	9:30	0		80%	19%	0	0
Athlete 11	18	6	Weights and swimming	0	41	0	3	3	6	5	0	Fairly Good	9:04	9:00	9:30	0		60%	38%	0	0
Athlete 12	18	2	0	0	52	0	4	4	6	9	0	Fairly Good	8:04	8:00	8:30	0		80%	25%	0	0
Athlete 13	18	4	V02, Back end efforts, speed kick, pull, aerobic	0	53	0	4	4	7	8	0	Very Good	8:30	8:00	10:00	2	Greater than 0.5 but less than 1 hour	80%	6%	0	0
Athlete 14	14	1	Swimming, stretching, core	0	39	0	3	3	4	7	0	Fairly Good	7:15	6:30	10:30	1	Greater than 1 but less than 1.5 hours	60%	31%	0	0
Athlete 15	10	4	Swimming and running	0	23	0	4	4	7	8	0	Fairly Good	8:38	8:00	8:00	2	Greater than 2 but less than 2.5 hours	80%	31%	0	0
Athlete 16	13	0	race simulation, skills, heart rate	4	30	1	5	5	8	8	0	Fairly Good	8:23	7:00	10:00	3	Greater than 2 but less than 2.5 hours	72%	44%	0	0
Athlete 17	0	0		0	0	0					0					0				0	0
Athlete 18	16	4	Swimming, gym, cycling	0	52	0	4	5	4	8	0	Very Good	7:38	7:30	8:30	0		76%	31%	0	0

Description Key

Variable	Explained	Colour Coding Information	Recommendations
Swimming Training Hours and KM	Acute:Chronic Workload Ratio - Provides an indication of whether the athlete's recent acute workload (current week) is greater, less than or equal to the workload that the athlete has been prepared for during the preceding chronic period (past 4 weeks) (Gabbett, 2016)	Red: ≥ 2 SD change from an athletes previous 4 week average (excludes weeks have not complete the AMQ) Amber: 1.4-2 SD change from an athletes previous 4 week average (excludes weeks have not complete the AMQ)	Based on recommended guidelines (Topp et al., 2015), we highlight wellbeing scores less of than or equal to 50% as an indication of potential low mood and well-being in the athlete and would be worth following up
Readiness/Motivation to Train	How often has the athlete felt ready/motivated to train this week? 0 = at no time, 5 = all the time	Lighter blue indicates 1 SD change from the athletes rolling average with an arrow to indicate the direction of change (excludes weeks have not complete the AMQ)	
Perceived Recovery	Generally, how well recovered has the athlete felt this week? 0 = very poorly recovered, 10 = very well recovered		
Rate of Perceived Exertion	Generally, how hard has the athlete thought they have worked this week? 0 = at rest, 10 = maximal	Darker blue indicates 2 SD change from the athletes rolling average with an arrow to indicate the direction of change (excludes weeks have not complete the AMQ)	
Total Daily Sleep	This refers to the total sleep in an average 24 hour period - i.e. average night sleep on training days based on a 6 day training week plus average night sleep on 1 rest day per week, plus total average napping. Formula = ((6 days * training day sleep) + (1 day * rest day sleep) + (days napping * average nap duration))/7	Red: 6 hours or less total sleep in a 24 hour period Amber: 7 hours or less total sleep in a 24 hour period	Based on recommended guidelines for the general population (Hirschkowitz et al., 2015), the recommended amount of sleep is 8-10 h for 14-17 year olds, and 7-9 h for 18-25 year olds.
Perceived Well Being	Higher percentage indicates better well being	Lighter blue indicates 1 SD change from the athletes rolling average with an arrow to indicate the direction of change (excludes weeks have not complete the AMQ)	
Perceived Stress	High percentage indicates high perceived stress	Darker blue indicates 2 SD change from the athletes rolling average with an arrow to indicate the direction of change (excludes weeks have not complete the AMQ)	

Appendices 4.6: Descriptive weekly mean data for the AMQ

Variable	Mean	Std. Deviation
Sport Specific Training Hours (hh: mm)	11:30	06:44
Other Training Hours (hh: mm)	04:37	03:51
Competition Hours (hh: mm)	01:25	03:39
Swimming Distance (km)	32.5	20.6
Days Competed	0.4	1.0
Number of Races	1.0	2.4
Perceived Readiness to Train *	3.8	0.9
Perceived Recovery *	6.4	1.6
Perceived Exertion *	5.7	1.9
Perceived Motivation *	3.9	0.9
Full Participation without Health problems (%)	86.5	34.2
Full Participation with ha health problems (%)	7.0	25.5
Reduced Participation due to health problems (%)	5.8	23.4
Cannot Participate due to health problem (%)	0.7	8.4
No Reduction in Training Volume (%) **	91.4	28.1
Mild Reduction in Training Volume (%) **	4.9	21.5
Moderate Reduction in Training Volume (%)**	2.4	15.2
Major Reduction in Training Volume (%) **	0.9	9.7
No Effect on Performance (%) **	89.1	31.2
Minor Effect on Performance (%) **	5.7	23.2
Moderate Effect on Performance (%) **	3.8	19.1

**Major Effect on Performance (%) ** **	0.8	9.1
**No Symptoms Health Complaints (%) ** **	90.4	29.5
**Mild Symptoms Health Complaints (%) ** **	6.2	24.0
**Moderate Symptoms Health Complaints (%) ** **	3.2	17.6
**Severe Symptoms Health Complaints (%) ** **	0.2	4.9
Prevalence of Injury (%)	6.2	24.0
Prevalence of Illness (%)	7.3	26.1
Prevalence of Health Problem (%)	13.5	34.2
Days Missed	0.1	0.5
Train Day Hours Sleep	07:53	01:06
Rest Day Hours Sleep	09:27	01:07
Average Sleep in 24 Hours (hh: mm)	08:55	22:43
Very Good Sleep Quality (%)	42	49
Fairly Good Sleep Quality (%)	53	50
Fairly Bad Sleep Quality (%)	5	21
Very Bad Sleep Quality (%)	1	8
Sleep Disturbance (%)	36	48
Sleep Latency (%)	44	50
Days Napping	1.2	1.4
Nap Length (hh: mm)	00:57	00:56
Bed Time on Training Days (hh: mm)	22:14	00:49
Wake Time on Training Days (hh: mm)	06:36	01:48
Bed Time on Rest Days (hh: mm)	22:39	01:03
Wake Time on Rest Days (hh: mm)	09:11	01:21

Perceived Wellbeing (%)	73	15
Perceived Stress (%)	24	16

Note.

* Readiness/Motivation to Train where 0 = at no time, 5 = all the time. Perceived Recovery where 0 = very poorly recovered, 10 = very well recovered. Rate of Perceived Exertion where 0 = at rest, 10 = maximal.

** due to health problem

Appendices 4.7: Feedback questions for athletes

1. Please indicate three highlights of your experience on the Swim England Performance squad thus far.

2. Please indicate three challenges you have faced on the Swim England Performance squad thus far.

3. What improvements could be made to the Swim England Performance Squad in your opinion?

Appendices 4.8: Results from the mixed measures ANOVA on the athlete PSS data at three time points (T)

Time Point 1 (T1) – April 2020

Time Point 2 (T2) – October 2020

Time Point 3 (T3) – April 2021

	Mean at T1	Mean at T2	Mean at T3
Competence	4.38	4.39	4.64
Autonomy	4.52	4.36	4.67
Relatedness	4.84	4.46	4.86
Mental Toughness	3.88	3.89	4.14
Adverse Response to Failure	2.69	2.43	2.36
Imagery and Active Prep	3.22	3.21	3.55
Self-directed Control and Management	3.72	3.82	3.86
Perfectionistic Tendencies	2.47	2.68	2.36
Seeking and Using Social Support	3.91	4.04	4.00
Active Coping	4.03	4.04	4.32
Clinical Indicators	2.25	2.32	2.23
Self Esteem	3.84	4.04	4.00
Intrinsic Motivation	4.06	4.07	4.23
Integrated Motivation	4.22	4.18	4.27
Identified Motivation	4.03	4.29	4.36
Introjected Motivation	4.00	3.79	3.82
Eternal Motivation	2.44	2.00	1.73

Amotivated	1.44	1.43	1.14
Individual Consideration	4.47	4.54	4.59
Inspirational Motivation	4.22	4.23	4.50
Intellectual Stimulation	4.31	4.23	4.32
Acceptance of Group Goals	4.06	4.27	3.82
High-performance Expectations	4.63	4.81	4.55
Appropriate Role Model	4.19	4.46	4.18
Contingent Reward	4.09	4.19	4.18
Autonomy Support	4.34	4.62	4.45
Structure	4.31	4.65	4.45
Involvement	3.94	4.42	4.41
Commitment	4.47	4.65	4.68
Closeness	4.50	4.81	4.77
Complementarity *	4.43	4.85	4.64
Responsiveness	3.82	4.10	4.07
Observation	4.03	4.35	4.18
Effective Questioning	4.07	4.38	4.45
Goal Setting	4.33	4.54	4.64
Developmental Feedback	4.47	4.58	4.59
Motivational Feedback	4.47	4.35	4.50
Perceived Support	2.86	3.04	3.14
Emotional Social Media Support *	3.64	3.58	3.45
Negative Social Support	1.43	1.27	1.32
Instrumental Support	2.86	2.65	3.14

Organisational Support	3.43	3.73	3.27
Emotional Support *	4.64	4.73	4.41
Esteem Support	4.50	4.42	4.41
Informational Support	4.46	4.73	4.50
Tangible Support	4.21	4.54	4.09
Comprehensibility	3.29	3.15	3.50
Manageability	3.64	3.77	3.59
Meaningfulness	4.00	3.77	3.95
Relationality	3.39	3.04	3.27

Note. * significant difference found between the three meantime points at $p<0.05$.

Supplementary material: PhD impact and dissemination

This PhD was funded by UK Sport with the aim of better understanding athlete and pathway development in a range of sports. To do so, we, as researchers, immersed ourselves within the participating sporting organisations. Developing relationships with the athletes, coaches and stakeholders of the participating sports was key to gaining consistent and rich data over the study period. As part of the engagement process, we had to ensure that each participant and the sport saw value in the data that we were collecting. One way in which we did this was through regular dissemination of the data back to athletes, coaches, and stakeholders in user-friendly formats. This included a series of individual and group weekly feedback reports, quarterly presentations, and narrated executive annual reports. Not only did these reports offer a summary of the data collected, but provided evidence to answer key questions regarding the performance pathway system, as well as provided an avenue for practitioners in sports to give their view on some of the interim research findings.

Below, I have provided examples of the feedback presentations I have provided throughout the project. In addition, I have included wider project dissemination such as a poster presentation at the English Institute of Sport National Conference 2019 and Canadian Society for Psychomotor Learning and Sport Psychology (SCAPPS) 2019. Additional impact pieces included annual sports reports for Swim England and British Rowing. These are not presented within this thesis but are available on request. It should be noted that whilst not presented below, further project dissemination meetings took place with the English Institute of Sports Pathways team annually.

6.1 Swim England 6-month feedback presentation

This presentation was produced after 6 months of data collection with the Swim England squad. We presented this presentation to the Performance Director and Sport Science Sports Medicine Manager of Swim England, the Head of Elite Development at British Swimming alongside other key staff members at Swim England (n=7).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Swim England Swimming
Pathway 2 Podium
PATHWAY 2 PODIUM
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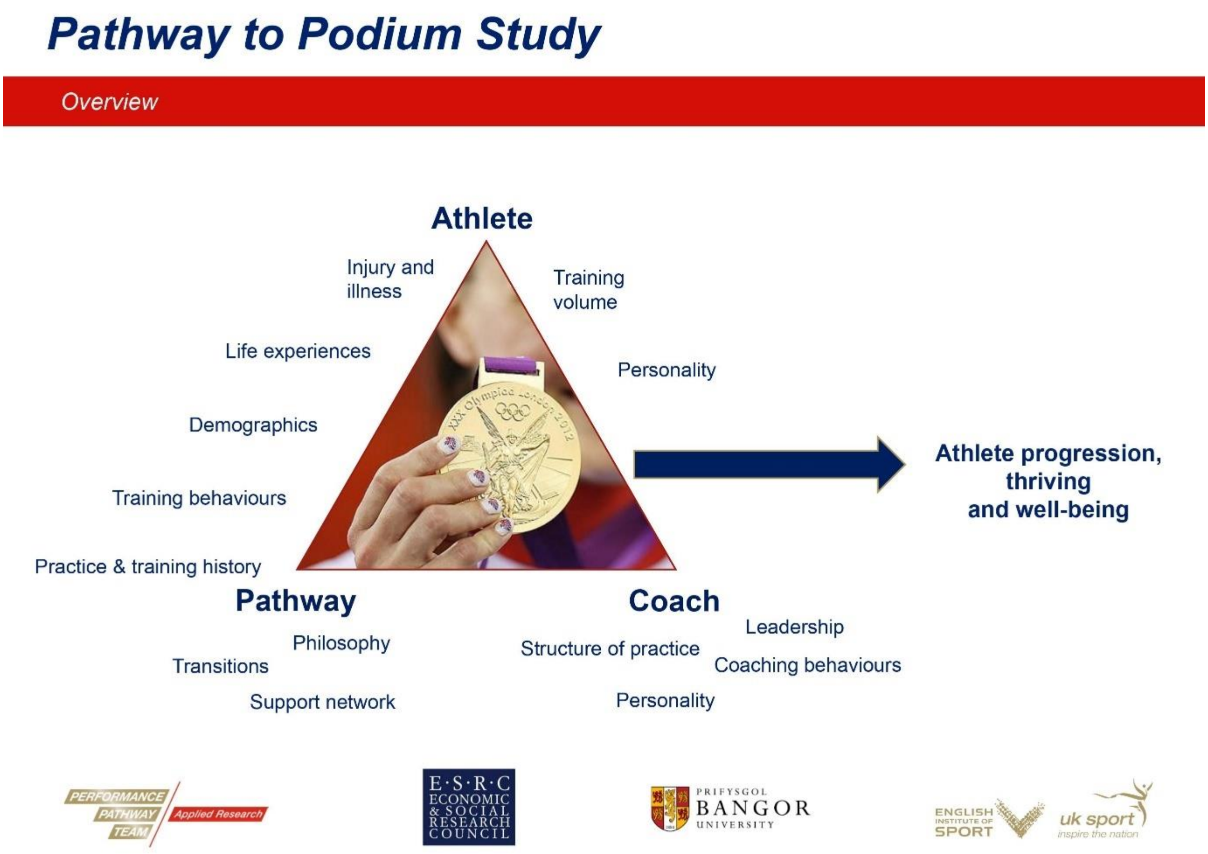
Pathway to Podium Study
Overview
Athlete
Injury and illness
Training volume
Life experiences
Personality
Demographics
Training behaviours
Practice & training history
Athlete progression, thriving and well-being
Pathway
Philosophy
Transitions
Support network
Coach
Leadership
Structure of practice
Coaching behaviours
Personality
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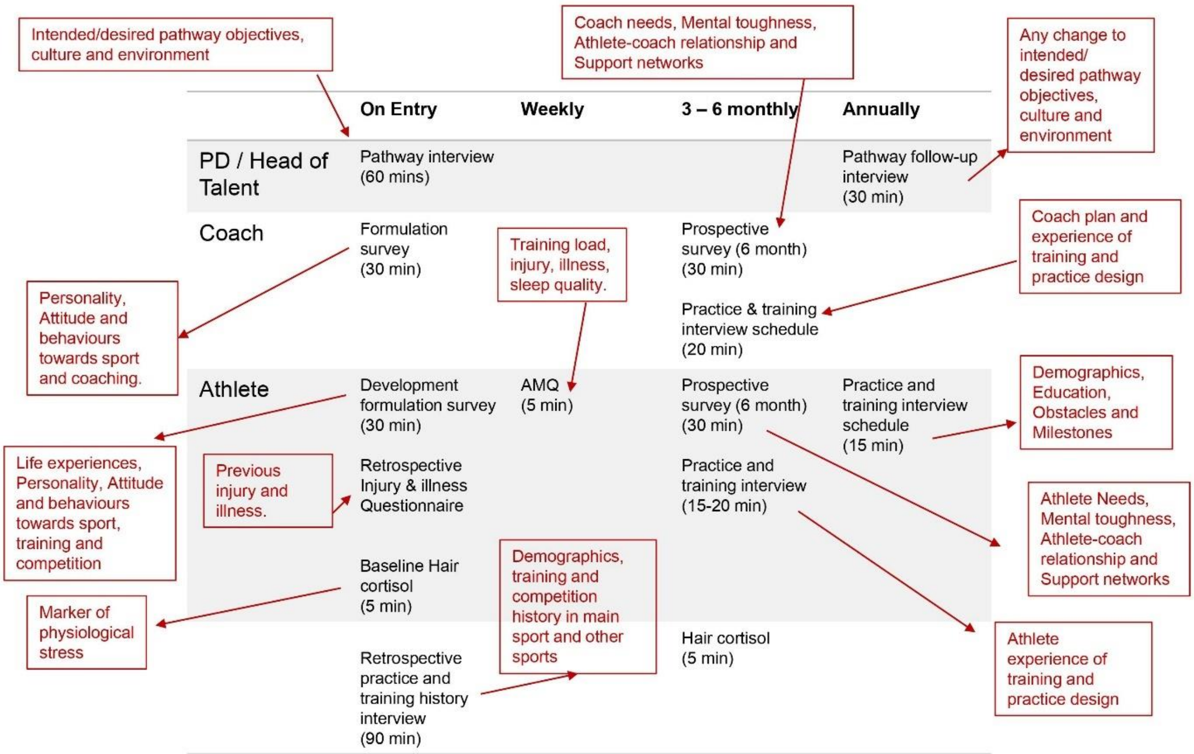


Swim England Swimming

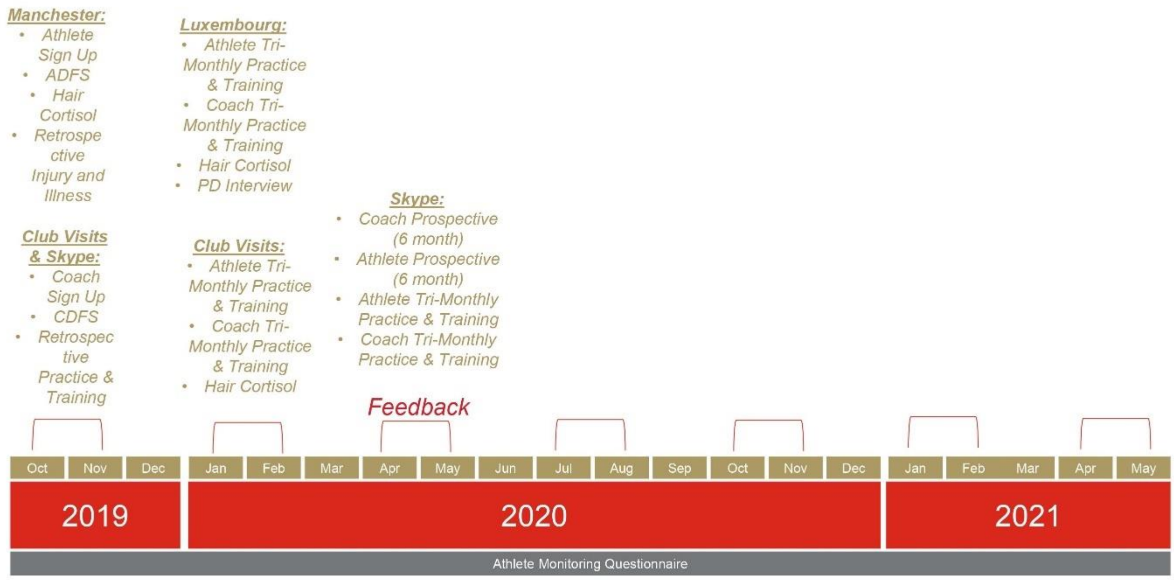
When? Start October 2019

Who? Performance Pathway Squad, 16 Athletes (6 Males, 10 Females, age 15-24y), 12 coaches

Where? Decentralised Sport

Collection so far…

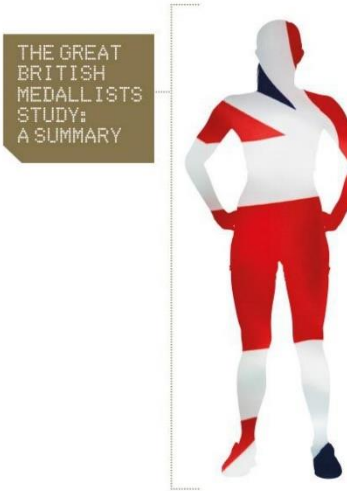
Time Scale



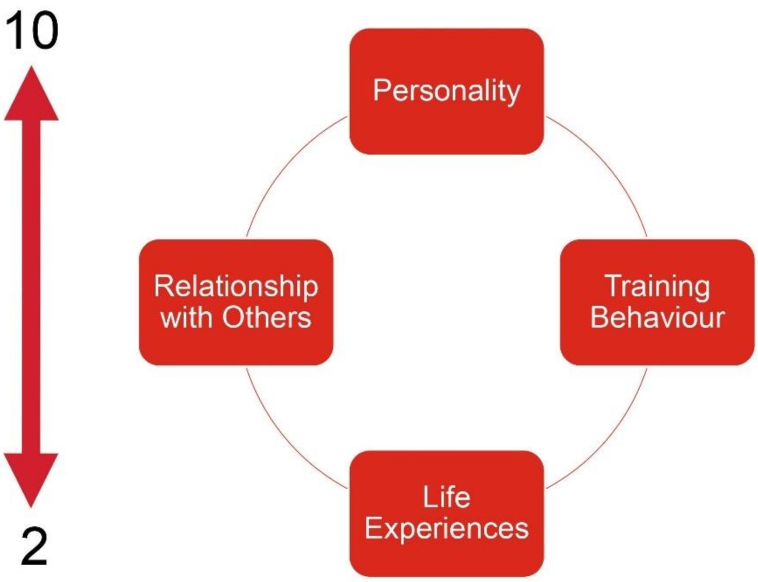
Athlete Development Formulation Survey (ADFS)

N =15

Background of ADFS…



What We Measured



Relationship with their Sport

Relative Importance of Sport

- Attraction of everyday life
- Competing influences
- Drawn away

1. *My sport is the most important thing in my life.*
2. *My sport offers me more than anything else in life (e.g. friends, family, relationships, money).*

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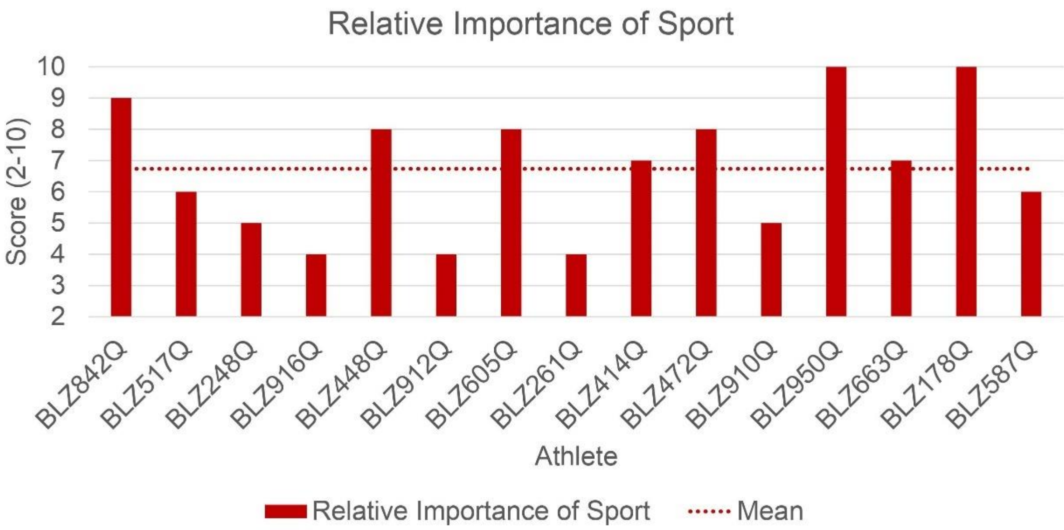
Relationship with their Sport

Relative Importance of Sport



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Approach to Training

Ruthlessness & Selfishness

RUTHLESSNESS

1. *I am willing to be disliked if it means being able to achieve my targets in sport.*

2. *When it comes to sport, I am ruthless when I need to be.*

SELFISHNESS

1. *In sport, I put my own interests before the interests of others.*

2. *When it comes to sport, you have to be selfish.*

- "Difficult" personalities
- Advantageous to performance
- Pursuit of goals

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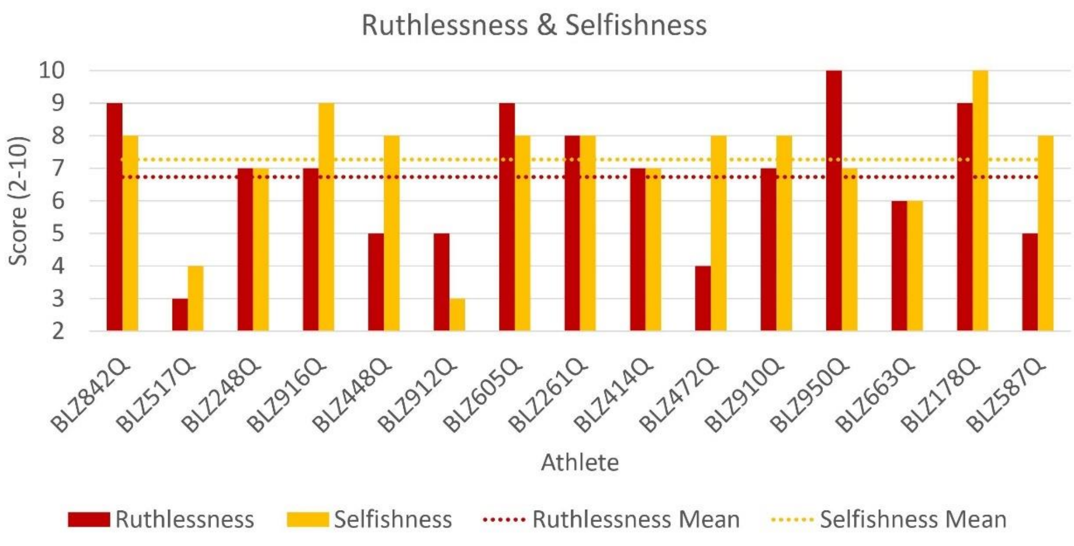
Approach to Training

Ruthlessness & Selfishness



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Approach to Competition

Outcome & Mastery Focus

Outcome Focus

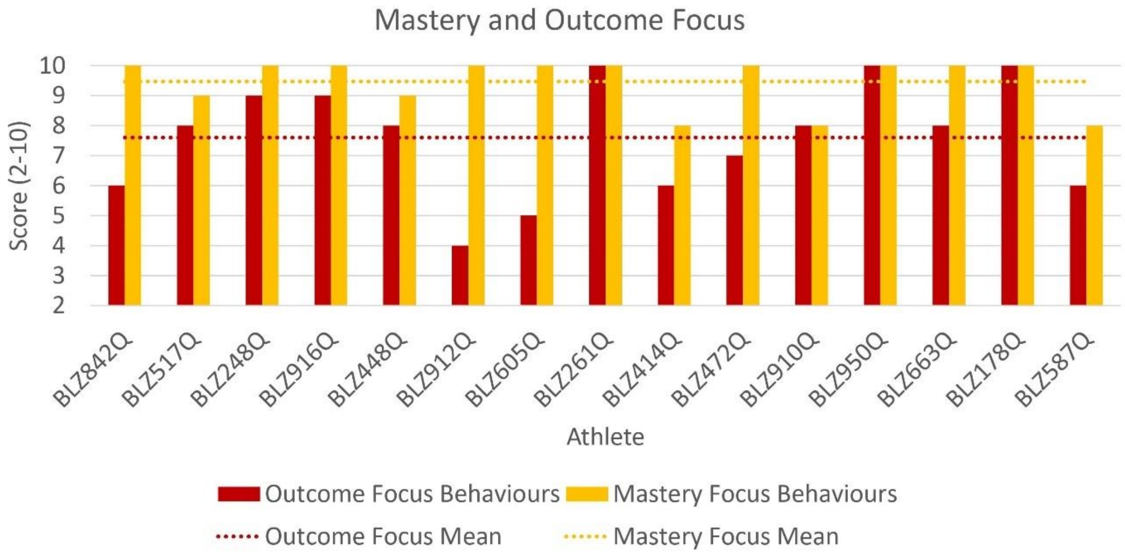
1. *When doing sport, I feel successful when I beat other people.*
2. *When doing sport, I feel successful when I outperform my opponents.*

Mastery Focus

1. *When doing sport, I feel successful when I perform to the best of my ability.*
2. *When doing sport, I feel successful when I show clear personal improvements.*

Approach to Competition

Mastery & Outcome Focus (Training / Competition Behaviours)



Approach to Competition

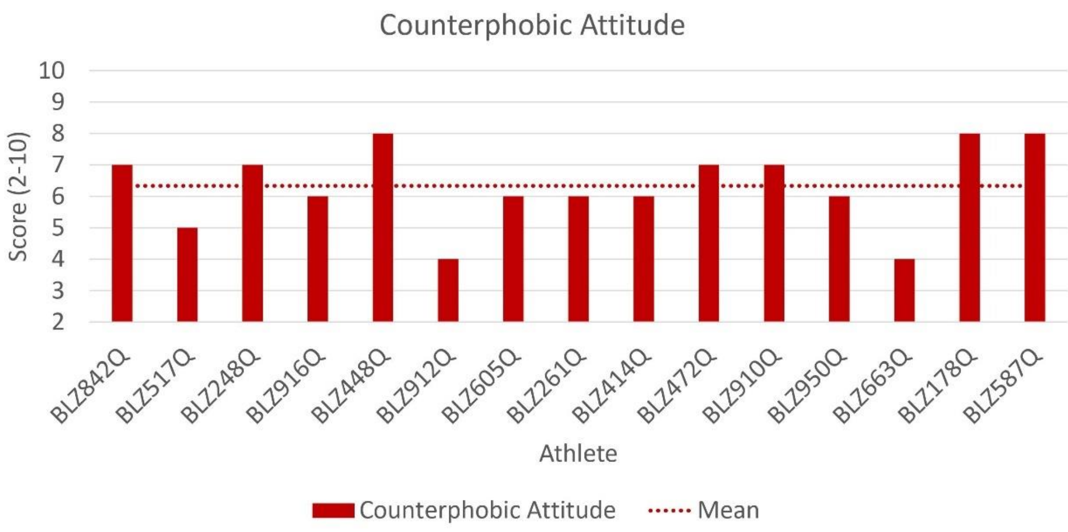
Counterphobic Attitude

- *Experience **specific, internal and intense** anxiety.*
- *Drawn towards anxiety-provoking situations.*
- *High level competition.*

1. *I am drawn to things I am afraid of.*
2. *I love how nervous competition makes me feel.*

Approach to Competition

Counterphobic Attitude



Approach to Competition

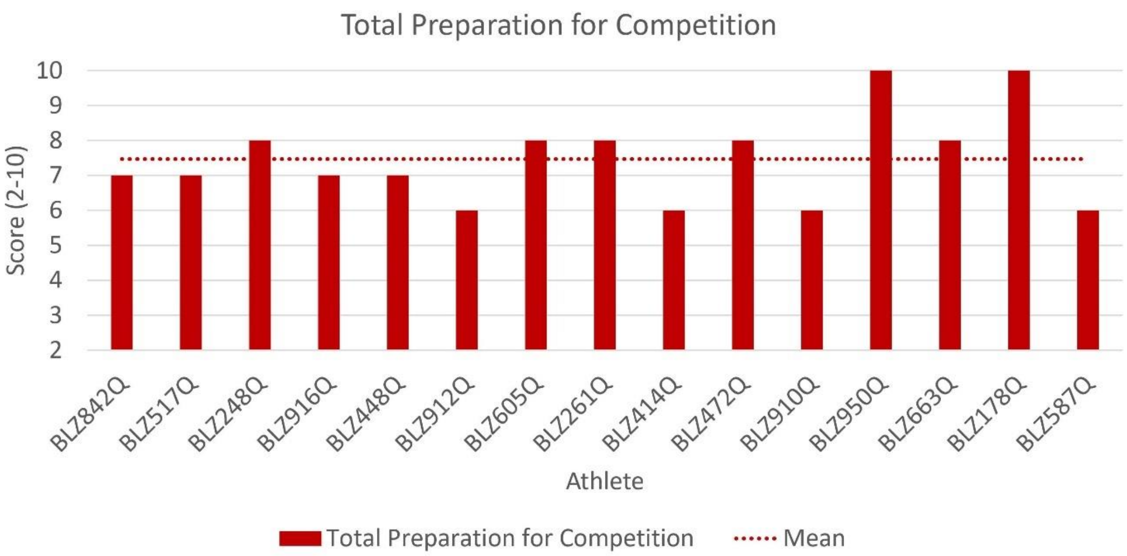
Total Preparation for Competition

- *All required preparation.*
- *"No stone unturned"*

1. *I leave no stone unturned in preparation for competition.*
2. *I go beyond the norm to prepare for competition.*

Approach to Competition

Total Preparation for Competition



Retrospective Practice and Training History Interview

N=16

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Specialisation in Swimming

Everyone had started swimming prior to the age of 6

Average total sports prior to swimming specialisation:

Mean (SD) = 4.6 (2.39)
(ranges from 1 – 9)

Most common sports	N
Football	6
Netball	5
Cross Country	5
Rugby	4
Cricket	4
Gymnastics	4

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Specialisation in Swimming

Start competing at age 8.6 years
(SD = 1.73) (range = 6 - 12)

Specialisation at 12.8 years
(SD = 2.77) (ranges = 9 - 17)

Athlete Monitoring Questionnaire (AMQ) Feedback

N=16

Athlete Monitoring Questionnaire

Weekly Questionnaire

<5 min to complete

76% Completion Rate

>24 Weeks (6 months)

- Training & Competition Volumes
- Readiness to Train & Perceived Exertion, Motivation & Recovery
- Perceived Stress & Well-Being
- Injury, Illness & Health Problems
- Sleep

Sleep

Sleep Hours (h) per night	Sleep Quality	Sleep Latency	Sleep Disturbance	Napping	Bed and Wake Time
Training Day 7.26h ± 1.13 h (max = 11.5h, min = 4.5h) Rest Day 9.52h ± 1.4h (max = 13.5h, min = 5h)	44% Very Good Sleep 49% Fairly Good Sleep 6% Fairly Bad Sleep 1% Very Bad Sleep	61% sleep within 30 mins every night	45% do not wake up throughout the night, 55% wake up throughout the night on at least one night per week	2 days napping per week for less than 1 hour.	Training Day: Bed Time: 77% go to bed between 9.30pm and 10.30pm Wake Time: 71% wake up between 4am and 6am Rest Day: TBC Bed Time: Wake Time:

Group	*n*	Time in bed (hrs:mins)
Controls	20	8:07 ± 0:20$_a$
Athletes	46	8:36 ± 0:53$_a$
Canoeing	*11*	*8:32 ± 0:35*
Diving	*14*	*8:46 ± 0:55*
Rowing	*10*	*7:46 ± 0:40*
Speed skating	*11*	*9:13 ± 0:47*

Sleep Duration and Quality in Elite Athletes
(Leeder et al., 2012)

Average Weekly Training Volumes

	Mean (SD)	Range
Weekly Sport Specific Training Hours (h) (i.e. time in the water)	14h (5.93h)	0-30h
Weekly Other Training Hours (h) (e.g. S&C)	3.57h (3.3h)	0-39h
Weekly Swimming Distance (km)	41km (19.5km)	0-81km
Weekly Competition Hours (h)	2.41 (4.54h)	0-22h
Weekly Number of Races	1.69 (3.07)	0-16

Health Problems

Total of 45 days missed training due to injury, illness or health problem,
Average 0.2 days missed due to injury, illness or health problem
Max 7 days missed

81% have full participation without health problems, 9 % full participation with health problem
10% had reduced participation due to health problem

4% reported injuries, 14% reported illnesses

30 new health problems reported over 6 months

Perceived Stress (Cohen, Kamarck & Mermelstein, 1983)

AMQ weekly average: *24%* *(max = 81.25%, min = 0%)*

(higher scores indicate higher stress levels)

PSS-4 mean score for English general population *(Warttig et al., 2013)*

38% *(age 16-85 year olds, n =1484),*

43% *(<18 years, n = 22),*

42% *(18-29 years, n = 409)*

Well-being (WHO-5, 1998)

AMQ weekly average: *72.1%* *(max = 100%, min = 16%)*

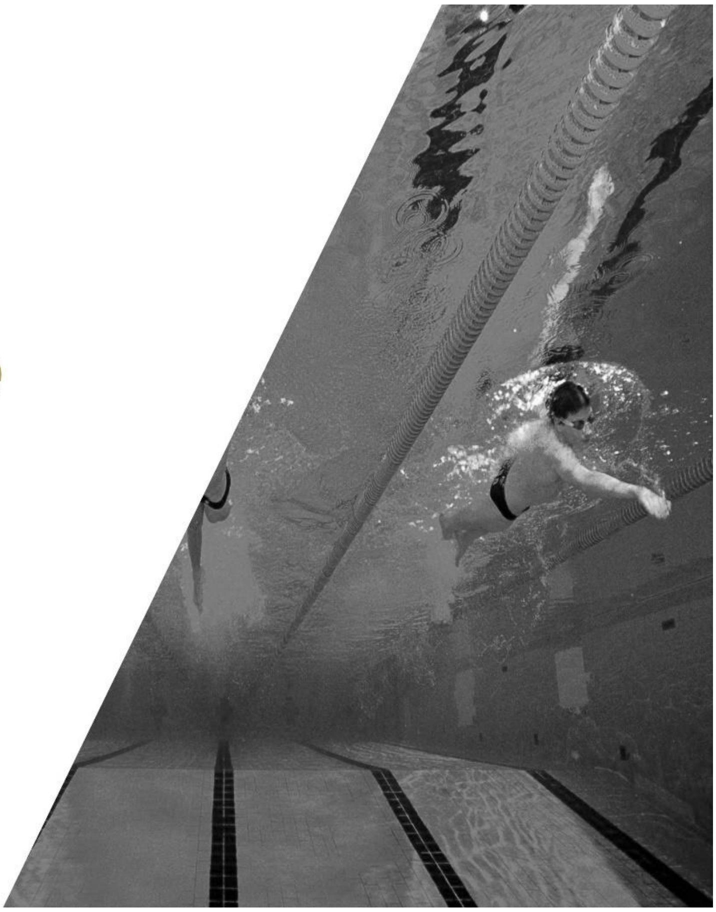
(higher scores indicate better well-being)

WHO-5 mean score for UK population in 2016 was *66%* *(age 18-24 year olds)*

(Randall, Cochrane, Jones & Manclossi, 2019).

When WHO-5 is used for the screening of depression in clinical trials, a cut-off score consistently lower than *≤50%* *is typically used* *(Topp et al., 2015).*

Covid-19… How are the athletes coping?



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Covid-19

- Additions to the AMQ (motivation, further detail on the types of training they are doing)
- Able to track their training, illness symptoms, wellbeing and stress during this time
- Practice & Training interview – reports from athletes include….
- Propose more regular contact with the athletes re: their training. Check in end of April with short interview to find out what kind of things they are doing.

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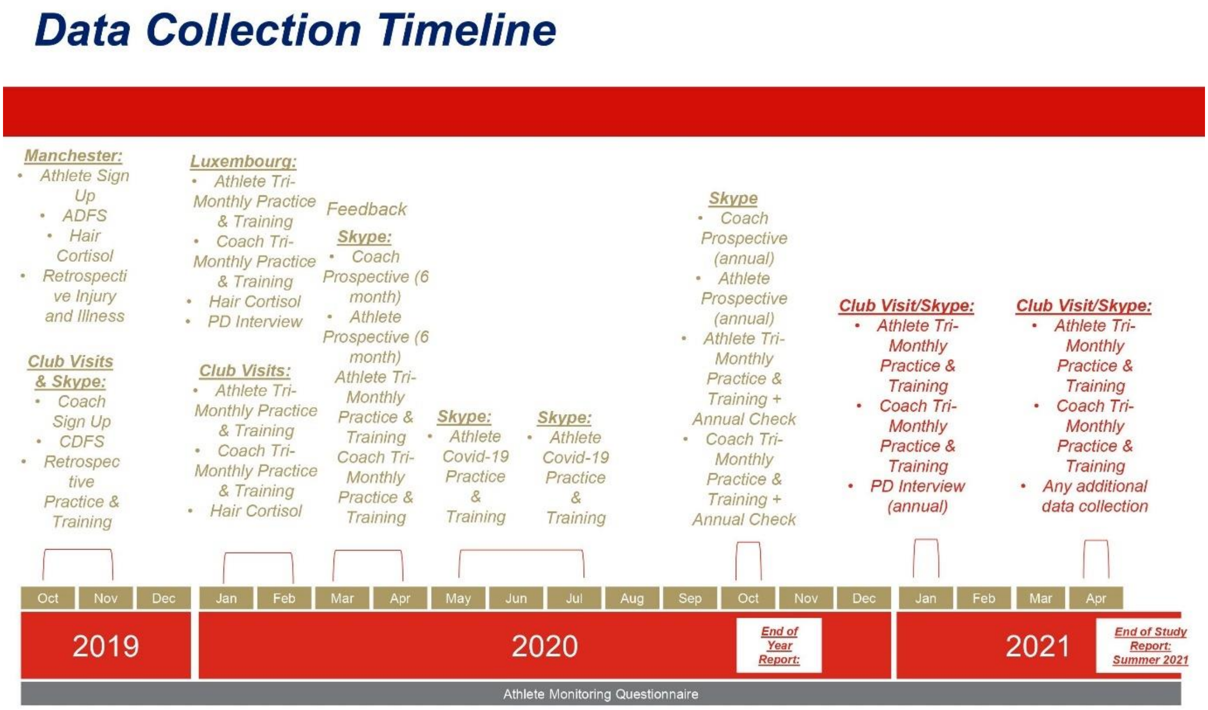

Data Collection Timeline
Manchester:
• Athlete Sign Up
• ADFS
• Hair Cortisol
• Retrospective Injury and Illness
Club Visits & Skype:
• Coach Sign Up
• CDFS
• Retrospective Practice & Training
Luxembourg:
• Athlete Tri-Monthly Practice & Training
• Coach Tri-Monthly Practice & Training
• Hair Cortisol
• PD Interview
Club Visits:
• Athlete Tri-Monthly Practice & Training
• Coach Tri-Monthly Practice & Training
• Hair Cortisol
Feedback
Skype:
• Coach Prospective (6 month)
• Athlete Prospective (6 month)
Athlete Tri-Monthly Practice & Training
Coach Tri-Monthly Practice & Training
Skype:
• Athlete Covid-19 Practice & Training
Skype:
• Athlete Covid-19 Practice & Training
Skype
• Coach Prospective (annual)
• Athlete Prospective (annual)
• Athlete Tri-Monthly Practice & Training + Annual Check
• Coach Tri-Monthly Practice & Training + Annual Check
Club Visit/Skype:
• Athlete Tri-Monthly Practice & Training
• Coach Tri-Monthly Practice & Training
• PD Interview (annual)
Club Visit/Skype:
• Athlete Tri-Monthly Practice & Training
• Coach Tri-Monthly Practice & Training
• Any additional data collection
Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr
2019
2020
End of Year Report:
2021
End of Study Report: Summer 2021
Athlete Monitoring Questionnaire

6.2 Swim England annual feedback presentation

This presentation was produced after 12 months of data collection with the Swim England squad. We presented this presentation to the Performance Director and Sport Science Sports Medicine Manager of Swim England and the Head of Elite Development at British Swimming.

Swim England
Swimming

Pathway 2 Podium
9th October 2020

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Agenda

First half	Second half
Key findings	P2P Project Planning

Athlete Monitoring & Availability Paper

Aim:

1) *To understand* ***which factors are most influential in determining the (un)availability*** *of developing and recreationally active athletes to train and compete.*
2) *To provide normative data across variables to allow for sport/population comparisons.*

Participants:

43 British development athletes from Rowing, Swimming, Canoe Sprint and Canoe Slalom (all pre-WCP)

91 recreationally active (RA) age-matched athletes from a variety of sports.

Method:

Participants completed the AMQ for 14 weeks (October 2019 - January 2020).

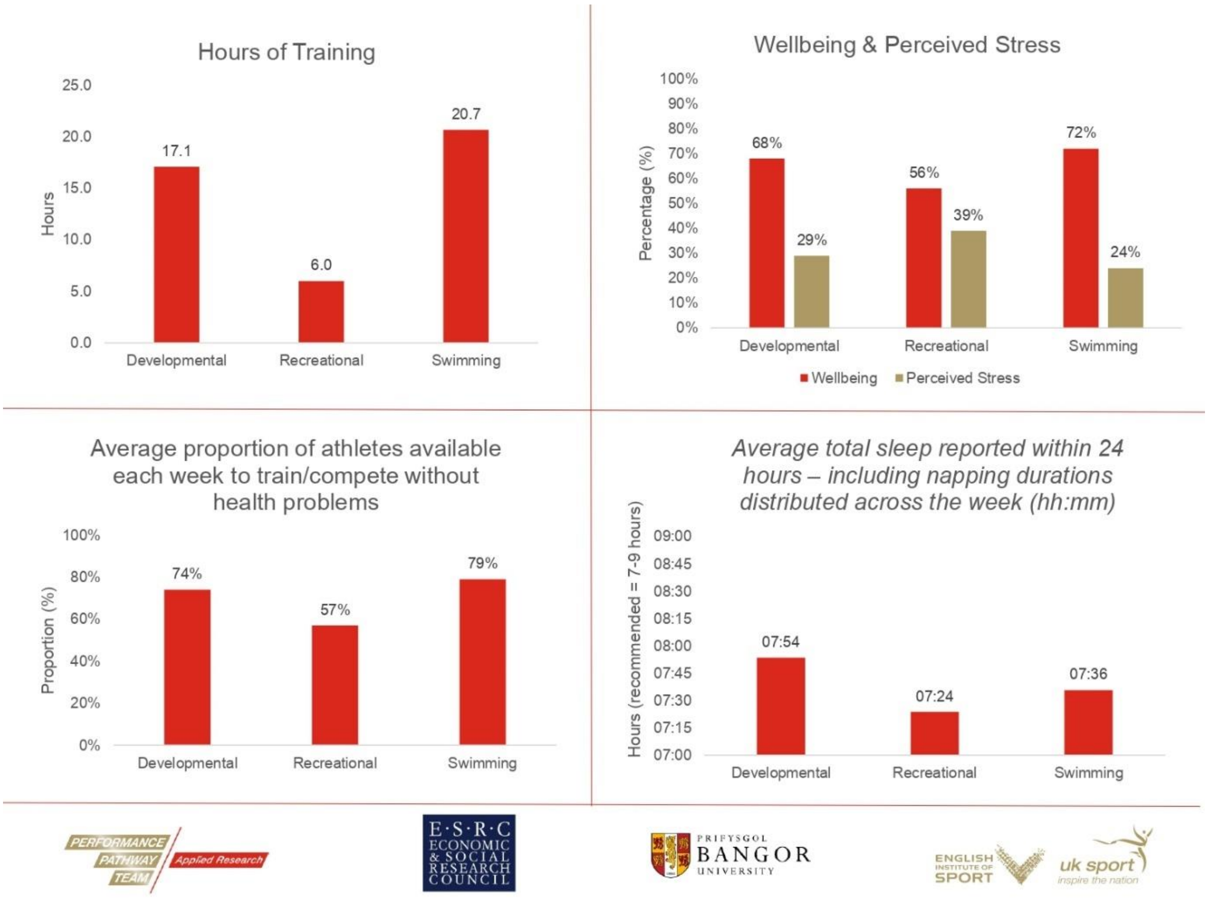
Key Messages

These developing athletes reported…

- ***higher volumes of training (at a higher perceived effort)***
- ***similar perceived recovery***
- ***higher readiness to train***
- ***better sleep behaviours (quality and quantity)***
- ***higher levels of wellbeing***
- ***lower levels of stress***
- ***fewer injuries (less substantial with fewer missed training days)***
- ***similar illness rates***

…in comparison to recreationally active athletes.

…sporting pathways are managing their athletes training, wellbeing and health well.


Hours of Training
Hours
25.0 20.0 15.0 10.0 5.0 0.0
17.1 6.0 20.7
Developmental Recreational Swimming
Wellbeing & Perceived Stress
Percentage (%)
100% 90% 80% 70% 60% 50% 40% 30% 20% 10% 0%
68% 29% 56% 39% 72% 24%
Developmental Recreational Swimming
Wellbeing Perceived Stress
Average proportion of athletes available each week to train/compete without health problems
Proportion (%)
100% 80% 60% 40% 20% 0%
74% 57% 79%
Developmental Recreational Swimming
Average total sleep reported within 24 hours – including napping durations distributed across the week (hh:mm)
Hours (recommended = 7-9 hours)
09:00 08:45 08:30 08:15 08:00 07:45 07:30 07:15 07:00
07:54 07:24 07:36
Developmental Recreational Swimming
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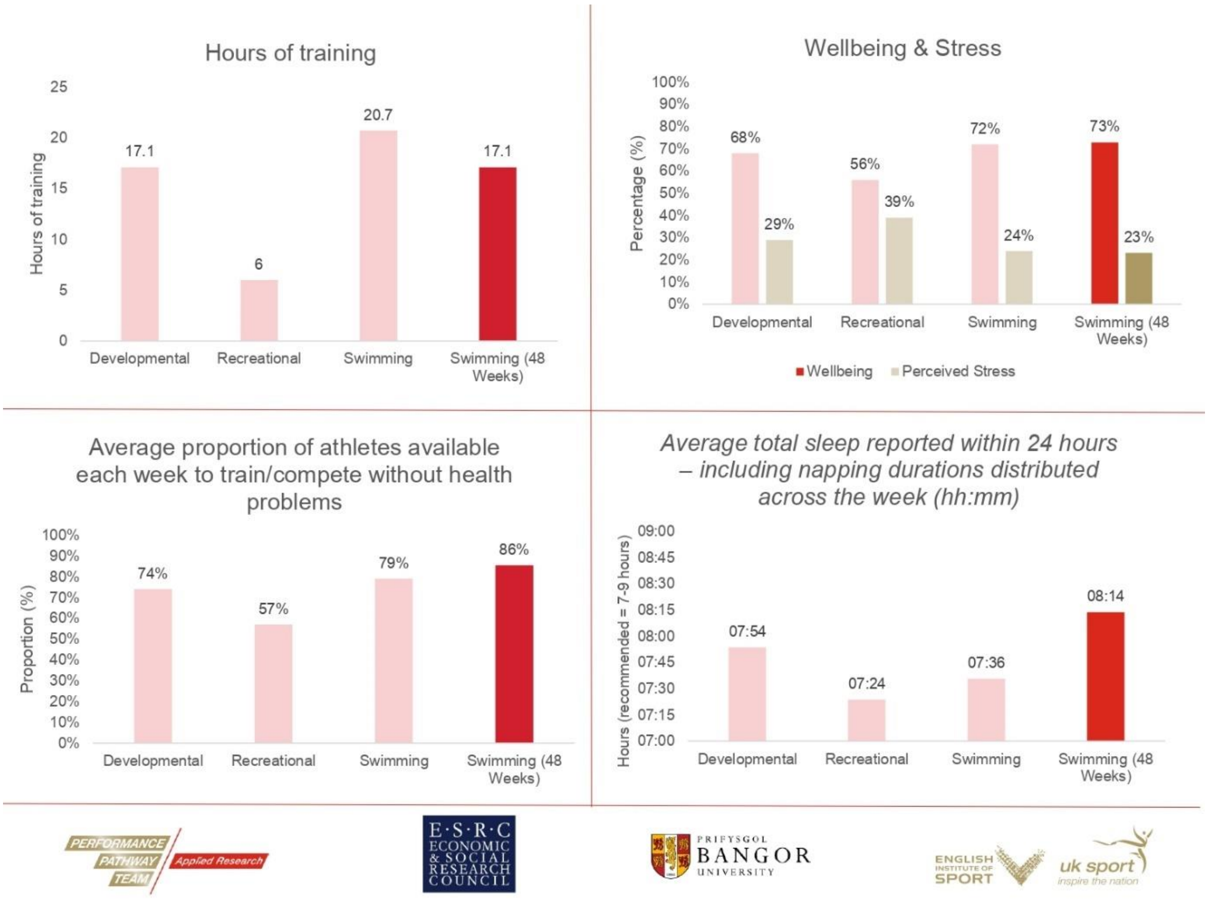
Hours of training
Hours of training
25 20 15 10 5 0
17.1 6 20.7 17.1
Developmental Recreational Swimming Swimming (48 Weeks)
Wellbeing & Stress
Percentage (%)
100% 90% 80% 70% 60% 50% 40% 30% 20% 10% 0%
68% 29% 56% 39% 72% 24% 73% 23%
Developmental Recreational Swimming Swimming (48 Weeks)
Wellbeing Perceived Stress
Average proportion of athletes available each week to train/compete without health problems
Proportion (%)
100% 90% 80% 70% 60% 50% 40% 30% 20% 10% 0%
74% 57% 79% 86%
Developmental Recreational Swimming Swimming (48 Weeks)
Average total sleep reported within 24 hours – including napping durations distributed across the week (hh:mm)
Hours (recommended = 7-9 hours)
09:00 08:45 08:30 08:15 08:00 07:45 07:30 07:15 07:00
07:54 07:24 07:36 08:14
Developmental Recreational Swimming Swimming (48 Weeks)
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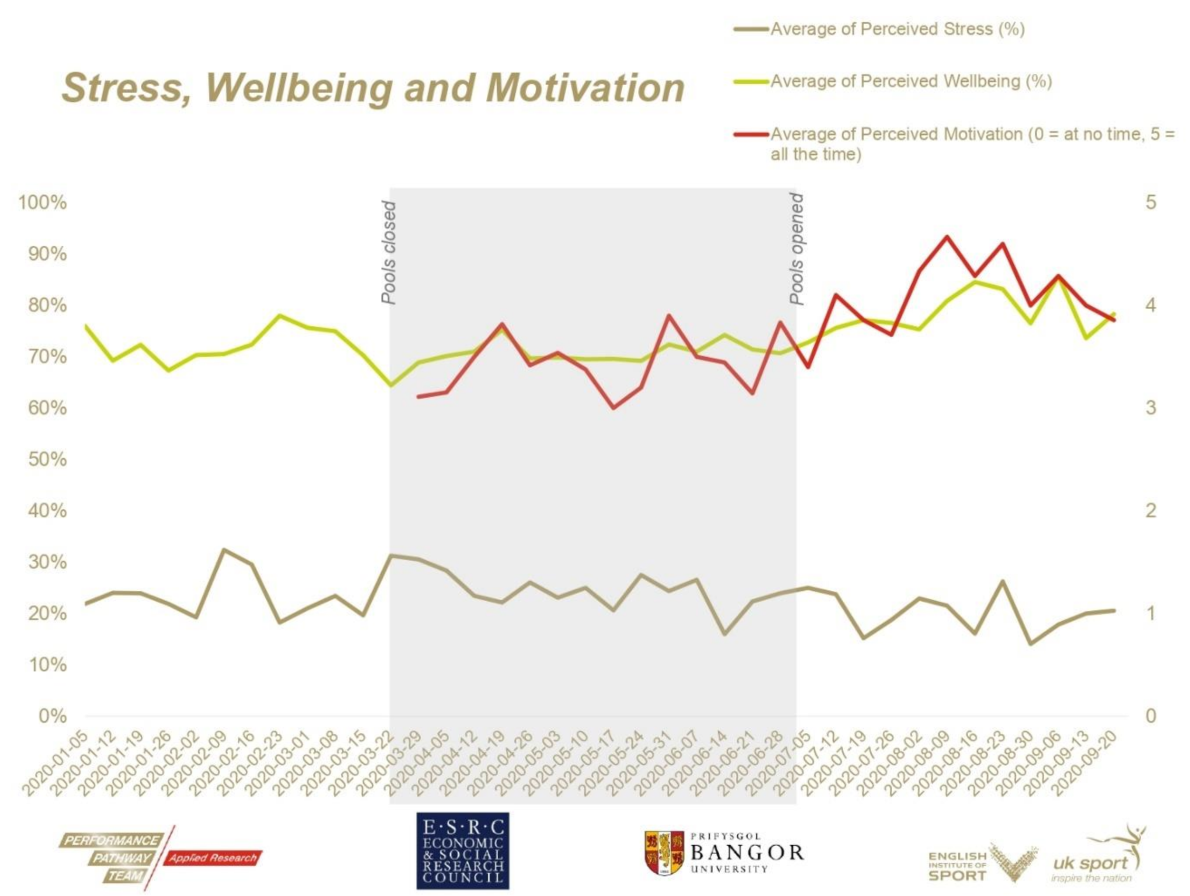
Stress, Wellbeing and Motivation
Average of Perceived Stress (%)
Average of Perceived Wellbeing (%)
Average of Perceived Motivation (0 = at no time, 5 = all the time)
Pools closed
Pools opened
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
5
4
3
2
1
0
2020-01-05
2020-01-12
2020-01-19
2020-01-26
2020-02-02
2020-02-09
2020-02-16
2020-02-23
2020-03-01
2020-03-08
2020-03-15
2020-03-22
2020-03-29
2020-04-05
2020-04-12
2020-04-19
2020-04-26
2020-05-03
2020-05-10
2020-05-17
2020-05-24
2020-05-31
2020-06-07
2020-06-14
2020-06-21
2020-06-28
2020-07-05
2020-07-12
2020-07-19
2020-07-26
2020-08-02
2020-08-09
2020-08-16
2020-08-23
2020-08-30
2020-09-06
2020-09-13
2020-09-20
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Average total sleep reported within 24 hours
- including napping durations distributed across the week
Sleep in 24 hours (hh:mm)
09:15
09:00
08:45
08:30
08:15
08:00
07:45
07:30
07:15
07:00
07:31
07:35
07:56
07:43
07:47
08:13
09:15
08:58
08:32
08:39
08:23
08:17
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
2019
2020
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P2P
Project Planning

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What are your thoughts?

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Deselection and selection

Deselection: any athletes leaving the programme?

- *Who?*
- *When?*
- *Why?*
- *Would you like any data collected?*
  E.g., exit interview, AMQ data etc.

Selection: any new athletes joining the programme?

- *Who?*
- *Coaches?*
- *Involvement in the project (data collection)*
- *When will they join?*
- *Require contact details*

Pattern Recognition: *Allows us to examine a large number of variables to identify which of these distinguishes between two different classifications or groups.*

Selection criteria for 2 groups

For example…

Performance markers

Commitment to the programme

Availability to train and compete

Progress

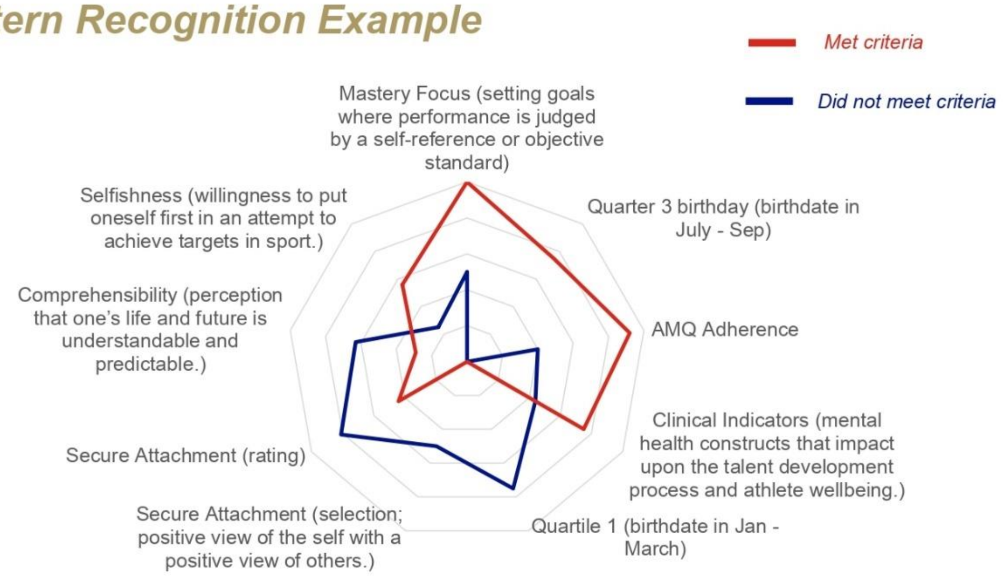
Wellbeing

Subjective rating

Experiential judgement

…etc.

Pattern Recognition Example

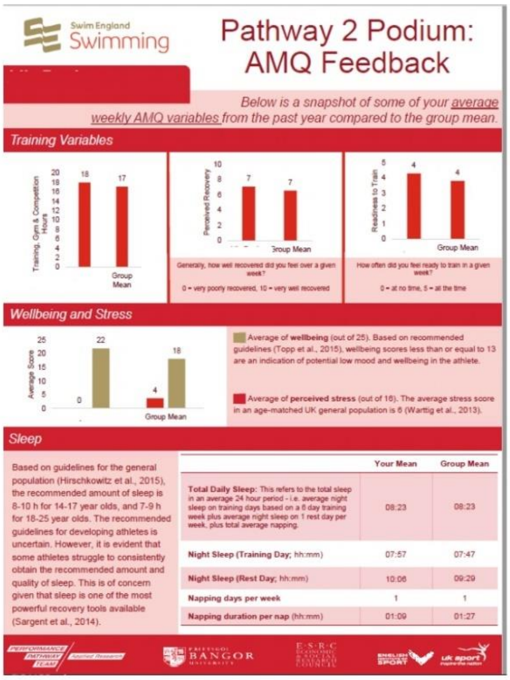


Feedback

Individual Athlete AMQ Averages Feedback

(to coaches as well)

25th September 2020



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Feedback in progress…

- ***Individual Athlete Feedback Report***

  Includes practice & training variables

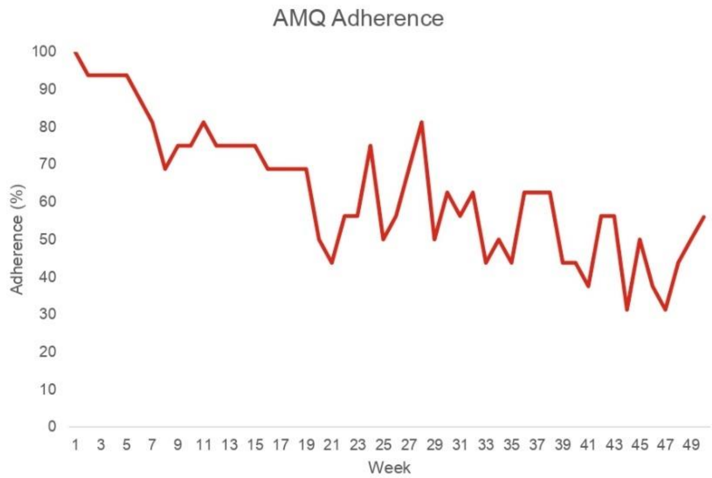
- ***Group Feedback Report***

  Includes practice & training variables + some psychosocial variables

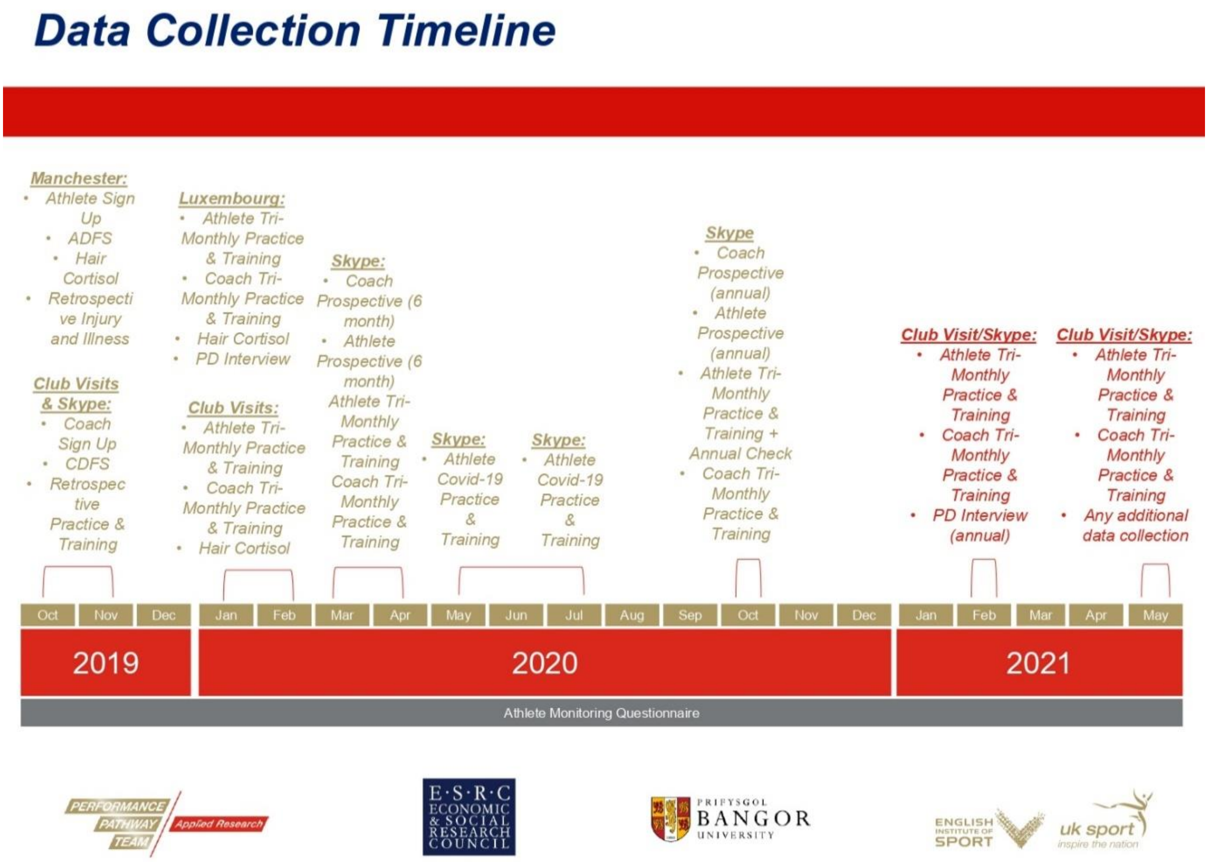
  + a narrated overview of the main points

Engagement

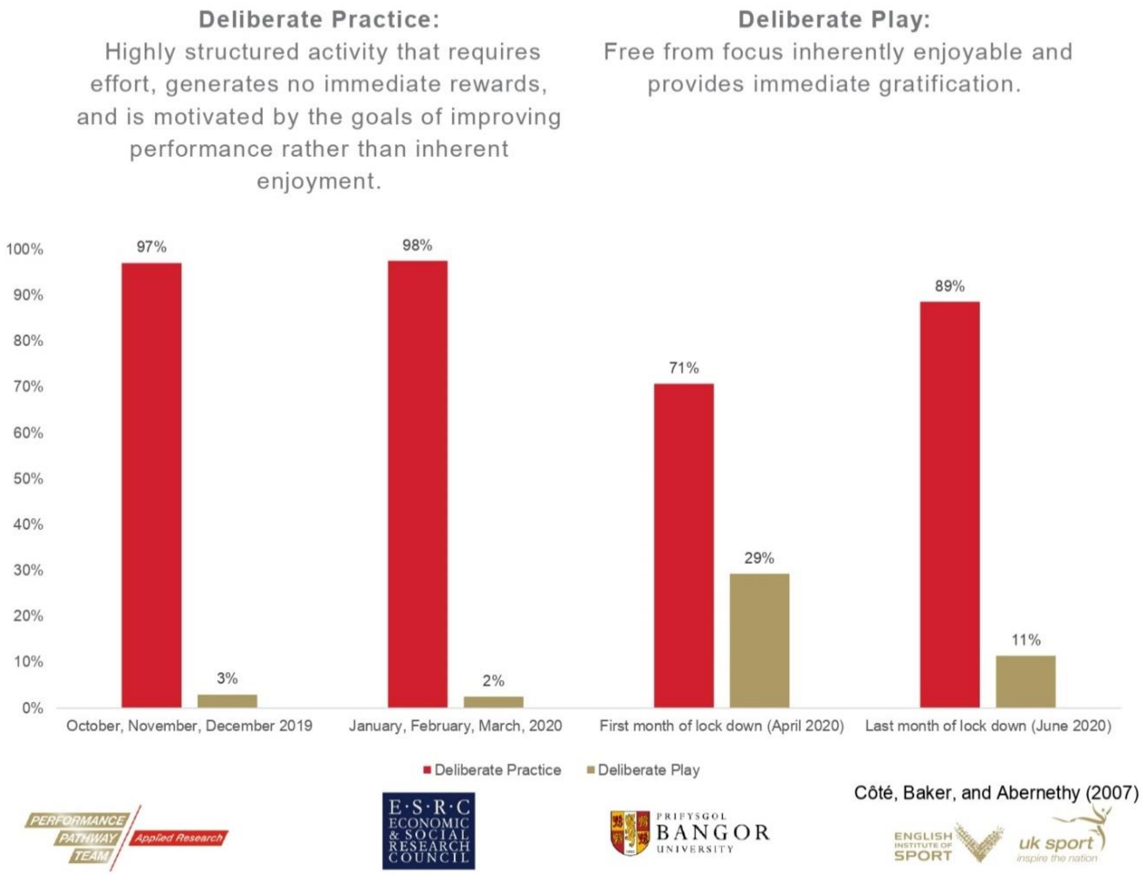
- *Coach engagement*
- *AMQ adherence*



Ideas to encourage engagement welcome!


Data Collection Timeline
Manchester:
Athlete Sign Up
ADFS
Hair Cortisol
Retrospective Injury and Illness
Club Visits & Skype:
Coach Sign Up
CDFS
Retrospective Practice & Training
Luxembourg:
Athlete Tri-Monthly Practice & Training
Coach Tri-Monthly Practice & Training
Hair Cortisol
PD Interview
Club Visits:
Athlete Tri-Monthly Practice & Training
Coach Tri-Monthly Practice & Training
Hair Cortisol
Skype:
Coach Prospective (6 month)
Athlete Prospective (6 month)
Athlete Tri-Monthly Practice & Training
Coach Tri-Monthly Practice & Training
Skype:
Athlete Covid-19 Practice & Training
Skype:
Athlete Covid-19 Practice & Training
Skype
Coach Prospective (annual)
Athlete Prospective (annual)
Athlete Tri-Monthly Practice & Training + Annual Check
Coach Tri-Monthly Practice & Training
Club Visit/Skype:
Athlete Tri-Monthly Practice & Training
Coach Tri-Monthly Practice & Training
PD Interview (annual)
Club Visit/Skype:
Athlete Tri-Monthly Practice & Training
Coach Tri-Monthly Practice & Training
Any additional data collection
Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May
2019
2020
2021
Athlete Monitoring Questionnaire


Any questions?


Deliberate Practice:
Highly structured activity that requires effort, generates no immediate rewards, and is motivated by the goals of improving performance rather than inherent enjoyment.
Deliberate Play:
Free from focus inherently enjoyable and provides immediate gratification.
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
97%
3%
98%
2%
71%
29%
89%
11%
October, November, December 2019
January, February, March, 2020
First month of lock down (April 2020)
Last month of lock down (June 2020)
Deliberate Practice
Deliberate Play
Côté, Baker, and Abernethy (2007)
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6.3 Swim England end of the data collection presentation

This presentation was produced after 18 months of data collection with the Swim England squad. We presented this presentation to the Performance Director and Sport Science Sports Medicine Manager of Swim England and the Head of Elite Development at British Swimming.

Swim England
Swimming

Pathway 2 Podium
Feedback

Agenda

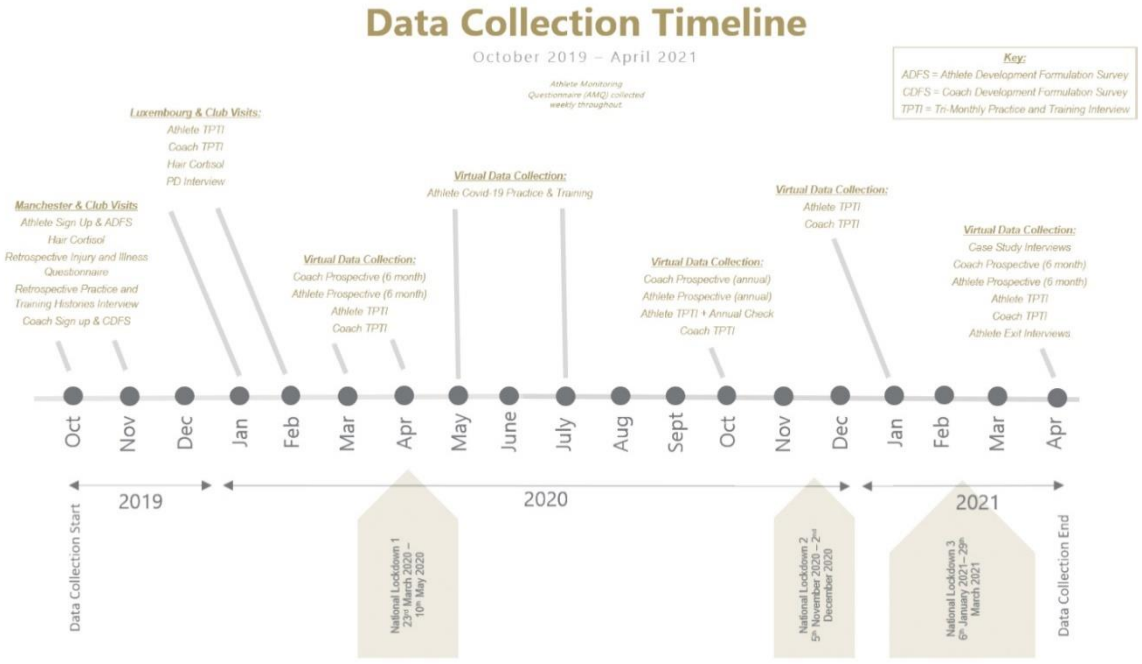
Key findings and implications

Psychosocial

Athlete Health

Practice and Training

Pattern Recognition Analyses



Participants

- 16 swimmers (10 females, 6 males, age 19.3 ± 1.9 years)
- 11 swimming coaches (all but one swimmer had coaches that participated in to the project)
- Head of Talent (Performance Director).
- 2 of the 16 swimmers were deselected from the programme in December 2020 and 1 swimmer retired from the sport in February 2021. Data for these three swimmers is included in the analyses.
- 3 additional swimmers (3 females, age 18 ± 3.5 years) and 1 coach joined and consented to participate in the study from 10th January 2021. We include their data where appropriate in the descriptive analyses but do not include their in data in the pattern recognition analyses.

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Psychosocial

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Prospective Psychosocial Survey

	Athletes	Coaches
Individual Consideration	4.5	4.6
Inspirational Motivation *	4.2	4.9
Intellectual Stimulation	4.3	4.6
Acceptance of Group Goals	4.1	4.7
High Performance Expectations	4.6	4.4
Appropriate Role Model *	4.2	4.9
Contingent Reward *	4.1	2.9
Autonomy Support	4.3	4.6
Structure *	4.3	4.9
Involvement *	3.9	4.9
Commitment	4.5	4.6
Closeness *	4.5	3
Complementarity	4.4	3.5
Responsiveness	3.8	4
Effective Questioning *	4.1	3.2
Goal Setting *	4.3	4.9
Developmental Feedback	4.5	4.9
Motivational Feedback	4.5	4.7

Note. * significant difference between the swimmer and coach mean data at $p<0.05$ with large effect sizes (Cohens d).

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Recommendation

We suggest that coaches and support staff reiterate the goals and aims of a meet/competition regularly before and during.

It is important that the goals and aims are mirrored vertically and horizontally throughout the pathway whereby there is a shared understanding and aims between all people at a given time-point, such that the athlete experiences consistent (and not contradicting) messages.

7

Athlete Health & Wellbeing

Findings

- The average completion of the weekly training questionnaire was 70% (±22%).
- Higher wellbeing and lower stress compared to the general population indicates positive mental health.
- At any given time, approximately 14% (two of the 16) of athletes experienced health problems.
  - 50% of those athletes were able to participate in training without any modifications despite the health problems
  - 50% of those athletes had to modify their training due or could not participate due to health problems.
- During COVID-19 athletes slept more. This finding further highlights that when not required to wake earlier for training, athletes chose to sleep more.
- Both sleep latency and sleep disturbance were prevalent (30% reported sleep latency and 49% reported sleep disturbance).

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Recommendation

Reducing sleep disturbance and latency by educating athletes on good sleep hygiene, and by considering moving training times where possible so athletes can obtain more night-time sleep, and encouraging daytime napping.

Swim England could look to include a form of periodised sleep throughout the year in line with training cycles.

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Recommendation

Implement some strategies to support wellbeing that they have used with athletes but with the coaches as well.

Something as "light-touch" as a quick check-in every few months to ask how coaches are coping by an appropriately trained and experienced person could be very effective here.

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Pattern Recognition Analyses

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Pattern Recognition

Allows us to examine a large number of variables to identify which of these distinguishes between two different classifications or groups.

Two groups:

1. *Swimmers who are more likely to progress through the high performance system **(Higher Potential)***
2. *Swimmers that were less likely to progress through the high performance system **(Lower Potential)***

Four Analyses:

1. ***Full Dataset***
2. *Practice and Training*
3. ***Psychosocial***
4. *Health, Training and Availability*

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Pattern Recognition:

Full Data Set

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Considerations

1. Combination of variables.

2. A different pattern of discriminating variables would likely emerge if a different criterion were used.

3. Not all variables are selected in the overall model; however, this does not mean that they are not important.

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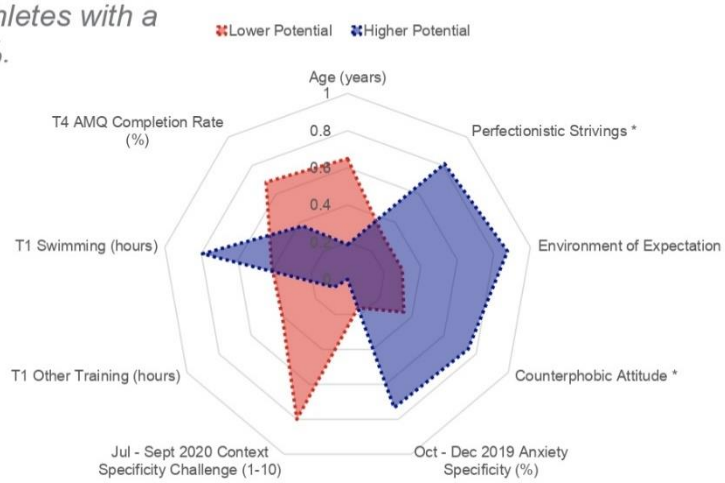
Pattern Recognition: Full Dataset

From the original 640 variables submitted to the analysis, a subset of only 9 variables were identified as discriminating between higher and lower potential athletes with a mean accuracy rating of 96%.



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Recommendation
To make training more challenging, a coach may utilise more constraints-led coaching as opposed to prescriptive coaching.
A constraints-led approach is characterised by the manipulation of task (e.g., session goal) and environment (e.g., training equipment) boundaries or instructions (i.e., constraints). By manipulating task and environment constraints, coaches can guide athletes to find solutions to sport problems through exploration and discovery.
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Pattern Recognition:
Psychosocial
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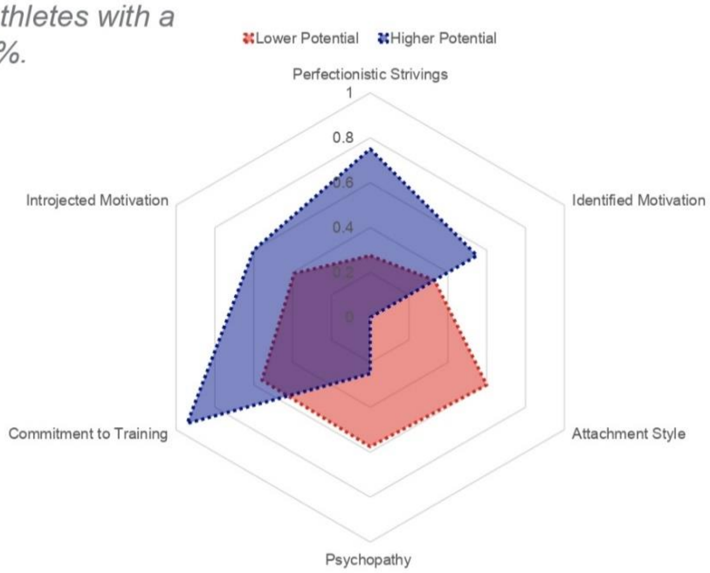
Pattern Recognition: Psychosocial Dataset

From the original 91 variables submitted to the analysis, a subset of only 7 variables was identified as discriminating between higher and lower potential athletes with a mean accuracy rating of 87%.



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Finding

The personality profile of these higher potential athletes is suggestive of a likeable and coachable individual/role model athlete.

The personality profile of these lower potential athletes may be perceived to be harder to coach. Whilst athletes of this particular profile are certainly likely to be more difficult to coach and work with, it is noteworthy that these traits are some of those that are found in super-elite athletes (Hardy et al., 2017).

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Recommendation

Swim England may want to consider who they are selecting / progressing and potentially losing as part of the selection process because of perceived personality characteristics and ease/difficulty to coach.

The personality profile of the lower potential athletes is in line with those of some previous super-elite athletes thus, we suggest that Swim England look at ways in which to support the coaches of these athletes and the athletes themselves in order to maximise their development and their ability to achieve their potential.

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Questions

Which aspects confirm your previous assumptions?

Any surprises?

Any further questions?

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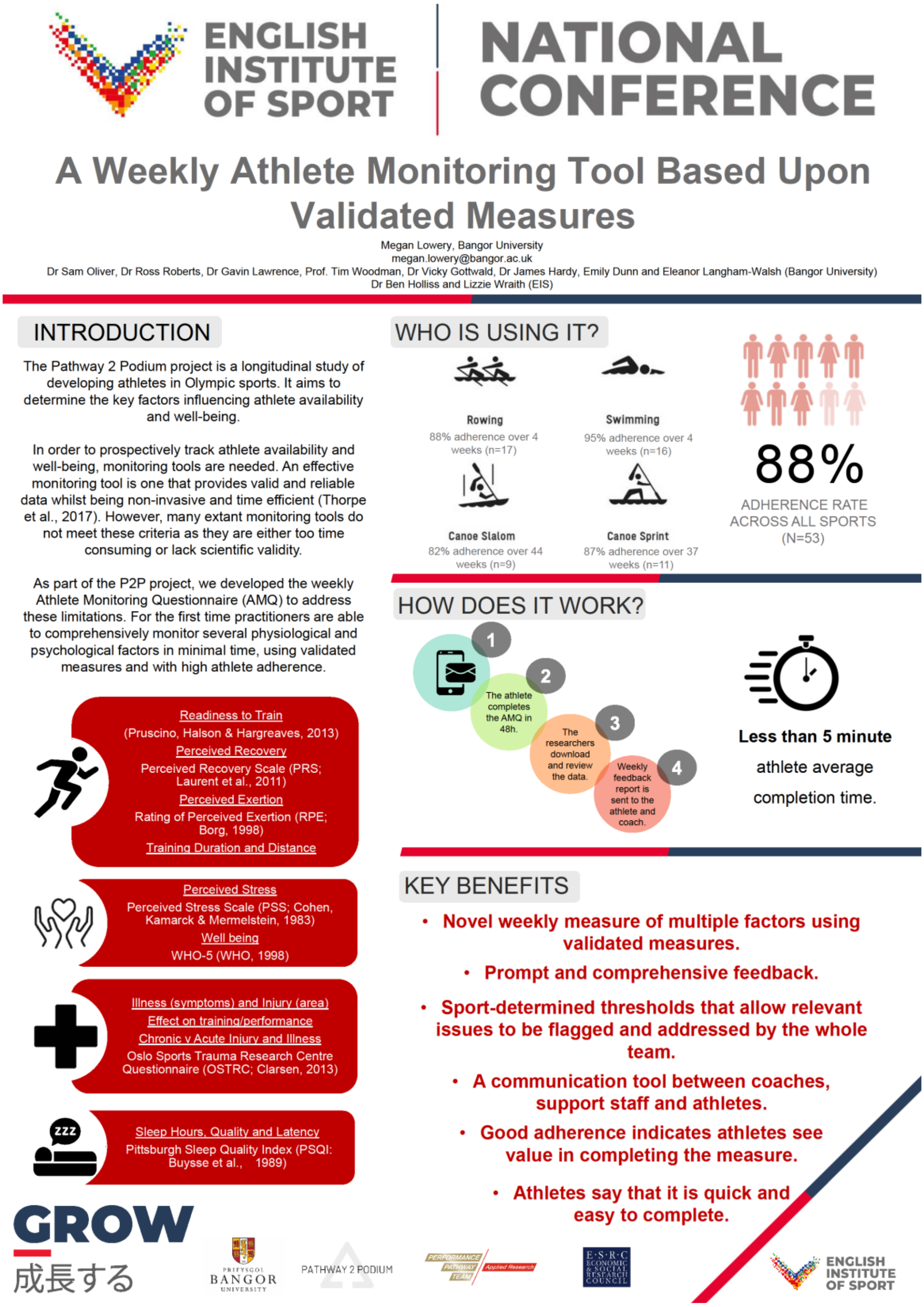
6.4 English Institute of Sport national conference 2019 poster presentation

This poster was presented once at the English Institute of Sport National Conference in December 2019 (n=400).



6.5 Canadian Society for Psychomotor Learning and Sport Psychology (SCAPPS) conference poster presentation 2019

This poster was presented once at the Canadian Society for Psychomotor Learning and Sport Psychology (SCAPPS) Poster Presentation 2019 by my colleagues Dr Eleanor Langham-Walsh and Miss Emily Dunn.

Langham-Walsh, E., Anderson, D., Dunn, E., Gottwald, V., Hardy, J., Hardy, L., Lawrence, G., Lowery, M., Oliver, S., Roberts, R., & Woodman, T. (2019). Initial steps in the validation of the athlete development formulation survey. *Journal of Exercise, Movement, and Sport (SCAPPS refereed abstracts repository), 51*(1), 115.

Preliminary Validation of the Athlete Development Formulation Survey (ADFS)

Emily Dunn, Dior Anderson, Eleanor Langham-Walsh, Megan Lowery, Prof. Lew Hardy, Prof. Tim Woodman, Dr Gavin Lawrence, Dr James Hardy, Dr Vicky Gottwald, Dr Ross Roberts & Dr Sam Oliver

Introduction

- Talent development is often measured through anthropometric factors, competition and motor performance tests (Gullich & Cobley, 2017).
- There is evidence that psychosocial factors are important in attaining international medals (Hardy et al., 2017).
- No one has yet compiled psychosocial factors important to athlete development into one practical tool.
- Aim of the study was to develop and undertake preliminary validation of the Athlete Development Formulation Survey (ADFS) using a non-traditional correlational method.

Method

Item Generation and Justification

- Initial pool of 190 items was generated from the manuscript of the Great British Medalists Project (Hardy et al., 2017) alongside items from existing questionnaires.
- Items were revised (Rust & Golombok, 2009).
- Two items per construct were generated* or used from existing measures.

Instrument Construction

1. **Life Experiences:** environment of expectation and achievement (EEA)*; strong work ethic (SWE)*; highly competitive environment (HCE)*; mastery focus (MF)*; and outcome focus (OF)*.
2. **Athlete Personality:** difficulty with emotional expression (DWE)*; counterphobic attitude (CA)*; need to succeed (NS)*; need to avoid failure (NAF)*; selfishness*; ruthlessness*; perfectionistic concerns (PC); perfectionistic strivings (PS); socially prescribed perfectionism (SPP); and obsessiveness*.
3. **Athlete Behaviours:** mastery focus; outcome focus; total preparation for competition (TPC)*; commitment to training (CT)*; and relative importance of sport (RIS)*.

Strongly Disagree | Somewhat Agree | Neither Agree nor Disagree | Somewhat Agree | Strongly Agree

Participants

Study 1

- 365 participants were recruited online through social media.

Life experiences n = 117 (M hours training per week = 5.61, SD = 4.70; M years participating in sport = 7.35, SD = 7.27). ***Personality*** n = 122 (M hours training per week = 6.18, SD = 5.29; M years participating in sport = 7.35, SD = 7.27). ***Training Behaviours*** n = 123 (M hours training per week = 5.86, SD = 5.16; M years participating in sport = 9.50, SD = 7.08).

Study 2

- 66 participants (M = 30, F = 36) recruited in university lectures (M hours training per week = 7.00, SD = 3.37; M years participating in sport = 7.34, SD = 2.84).

Procedure and Analysis

- Each construct (2 items) were correlated with an existing measure (see results).
- Bivariate and dissatenuated correlation, Cook's Distance (Cook, 1977) and attention questions (study 2) were used.
- Magnitude of correlations were reported with effect sizes (Cohen, 1988).

Results

Table 1. *Correlations between ADFS Life Experiences Constructs and Previously Validated Measures*

ADFS Variables	WOFO: Mastery		WOFO: Work Ethic		WOFO: Competitiveness		POSQ: Ego		POSQ: Task	
	Study 1	Study 2	Study 1	Study 2	Study 1	Study 2	Study 1	Study 2	Study 1	Study 2
Environment of expectation and achievement	.51** (1.00)	.37** (.80)								
Strong work ethic			.49** (.63)	.61** (.78)						
Highly competitive environment					.59** (.73)	.49** (.61)				
Outcome Focus							.36** (.46)	.57** (.62)		
Mastery Focus									.19 (.28)	.42** (.68)

Table 2. *Correlations between ADFS Personality Constructs and Previously Validated Measures*

	ADFS Variables	1	2	3	4	5	6	7	8	9	10
Study 1	Difficulty with Emotion	.40** (1.00)									
	Counterphobic Attitude		.34** (.50)								
	Need to Succeed			.27** (.41)							
	Need to Avoid Failure				.21* (.44)						
	Ruthlessness					.25* (.31)					
	Selfishness						.36** (.50)				
	Perfectionistic Concerns							.64** (.72)			
	Perfectionistic Strivings								.54** (.72)		
	Socially Prescribed Perfectionism									.58** (.75)	
	Obsessiveness										.70** (.92)
Study 2	Difficulty with Emotion	.46** (.93)									
	Counterphobic Attitude		.31* (.49)								
	Need to Succeed			.12 (.22)							
	Need to Avoid Failure				.14 (.23)						
	Ruthlessness					.42** (.52)					
	Selfishness						.30** (.39)				
	Perfectionistic Concerns							.67** (.74)			
	Perfectionistic Strivings								.60** (.76)		
	Socially Prescribed Perfectionism									.46** (.65)	
	Obsessiveness										.73** (.88)

Table 3. *Correlations between ADFS Athlete Behaviours Constructs and Previously Validated Measures*

ADFS Variables	POSQ: Ego		POSQ: Task		QTI		SRSB		IOS	
	Study 1	Study 2	Study 1	Study 2	Study 1	Study 2	Study 1	Study 2	Study 1	Study 2
Outcome Focus	-.48** (-.53)	.60** (.68)								
Mastery Focus			-.31** (.38)	.45** (.62)						
Total Preparation for Competition					.47** (.54)	.50** (.65)				
Commitment to Training							.50** (.60)	.33** (.49)		
Relative Importance of Sport									.39**	.24

Discussion

- Consistent preliminary validation was shown across both studies with increased correlations when measurement error was accounted for.
- Lower strength correlations may be due to non-domain specific measures.
- Further validation is needed within a large elite athlete population across different sports.
- These studies are the first steps toward a practical psychosocial survey to examine important factors known to impact athlete development.
- In applied practice the ADFS could be used as part of multidisciplinary approach to measure and athlete development.

References