A Behavioural Design Thinking Approach to Technology Innovation in Sports Nutrition

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Abstract

Since the early 1900's sports nutrition research has focused almost exclusively on increasing our understanding of nutrition's impact on metabolism, physiology and physical performance, facilitating the development of more robust fuelling, recover and performance strategies. The last 20 years in particular has played host to the most rapid period of growth and knowledge creation in the history of the discipline. However, the translation of this knowledge into practice, and ultimately athlete behaviours, remains slow. In parallel to the more recent rise of sports nutrition, the popularity and uptake of smartphones and mobile apps has exploded globally and been ubiquitously accepted as the norm. The need to understand and integrate these advancements in technology to support and enhance service provision, as well as accelerate the translation of knowledge to practice, in sports nutrition has been cited for its potential and is in need of development. Through a pragmatic paradigm and utilising innovation research methodologies, as well as behaviour change theory and design thinking, this thesis aimed to develop and pilot a mobile app digital intervention that caters to the needs of both the athlete and the practitioner in applied sports nutrition.

Study 1 explored, via a sequential mixed methods approach; how social media mobile apps are being used by sports nutritionists (*n* = 44) as part of their service provision to athletes, as well as capture their experiences and opinions of its use. Survey responses were reported as descriptive statistics. Findings indicated social media was used by 89% of sports nutritionists to support practice, of which 97% perceived its use to be beneficial. Interviews were thematically analysed and the findings demonstrated that, despite sports nutritionists embracing digital technology as an extension of practice, they reported both a lack of time and digital intervention training as challenges to using these technology tools in practice.

Study 2 explored, via a qualitative approach, athletes' (n = 41) experiences and opinions of communication strategies in applied sports nutrition, as well as their suggestions for future mobile app supportive solutions. Data was analysed using reflexive thematic analysis. Athletes were dissatisfied with the levels of personalisation in the nutrition support they receive. Limited practitioner contact time was a contributing factor to this problem. Athletes cited the usefulness of online remote nutrition support and reported a desire for more personalised technology that can tailor support to their individual needs.

Study 3 explored the design and pilot of an industry specific mobile app intervention implementing behaviour change theory and design thinking methodologies. A 5-step Behavioural Design Thinking approach was utilised. This included a 14-day pilot testing period and with national level athletes (n = 26). Empathy mapping in step 1 identified a fundamental mismatch between what practitioners report they are currently capable of delivering and what athletes describe they need. The behaviour change requirements and solution designed from steps 2 to 4 was a digital behaviour change intervention (DBCI), that enables athletes to create personalised and periodised daily nutrition plans. Pilot-testing, conducted at step 5, revealed participants planned 78.80% (SD = 29.24) of their scheduled training sessions in the app. The app was utilised on 85.96% (SD = 28.26) of the participants planned training days and 62.73% (SD = 32.53) of their non-training days. The average number of engagement sessions per day was 2.53 (SD = 1.84). The mean amount of time each participant spent on the app per day was 3.68 minutes (SD = 2.54).

This thesis provides a proof of concept that the piloted industry specific mobile app DBCI has the potential to address the problems of time and training being experienced by sports nutritionists, whilst also delivering on the personalisation expectations of athletes with a scalable and autonomy supportive solution. Future research should focus on understanding the longer-term trends in the effectiveness, usage and uptake of the developed mobile app DBCI on a larger scale and across both male and female populations. This will facilitate a more representative picture of the longer-term impact of the technology on the nutrition planning behaviours of athletes.

Publications

Publications of the work listed within this thesis are as follows:

Dunne, D. M., Lefevre, C., Cunniffe, B., Tod, D., Close, G. L., Morton, J. P., & Murphy, R. (2019). Performance Nutrition in the digital era – An exploratory study into the use of social media by sports nutritionists. *Journal of Sports Sciences*, 37(21), 2467–2474. https://doi.org/10.1080/02640414.2019.1642052

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Publications in preparation or under review listed within this thesis are as follows:

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Disseminations

Disseminations of the work listed within this thesis are as follows:

Event	Location	Description
IOC Postgraduate Diploma in Sports Nutrition – Lecture on Mobile Apps and Modern Communication Strategies in Sports Nutrition	Online Remote	The pre-recorded lecture was added to the annual syllabus of the online postgraduate sports nutrition qualification awarded by the International Olympic Committee.
What can we learn from the nutrition industry	Online, Remote	A one-day digital conference focusing on applied sports and exercise nutrition research. Findings from Study 1 and 2 were disseminated.

List of abbreviations

Abbreviation	Full Title
AI	artificial intelligence
>	greater than
<	less than
mHealth	mobile health
BCT	behaviour change technique
C	capability
O	opportunity
M	motivation
B	behaviour
BCW	Behaviour Change Wheel
TDF	Theoretical Domains Framework
MOA	mechanism of action
DBCI	digital behaviour change intervention
TA	thematic analysis
NBA	National Basketball Association
NFL	National Football League
MLB	Major League Baseball

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Chapter One:

General Introduction

This chapter provides a brief introduction to applied sports nutrition and the global trends in technology so as to provide a clear rationale to the Aims and Objectives of this thesis.

1.1 Introduction

The origins of sports nutrition can be traced back to ancient civilisations, such as the Greeks and Romans, where the athletes followed specialised diets in the hope that it would enhance their performance (Grivetti & Applegate, 1997). However, the field now known as sports nutrition evolved much later, with breakthroughs in technology facilitating its continual evolvement. Born out of the exercise physiology laboratories, historians consider the first studies of sports nutrition to be those exploring carbohydrate and fat metabolism by Nathan Zuntz and his co-workers (Zuntz, 1896; Frentzel & Reach, 1901; Zuntz 1901). Fuel sources for exercise activity was a topic that did not reach resolution until improvements in technology, specifically the cycle ergometer and a more precise chemical analyser, removed the uncertainty that came with the then available methodologies at that time (Krogh, 1913; Krogh, 1920). Another major breakthrough came during the "classic period" of exercise biochemistry when the development of the percutaneous needle biopsy by Bergstörm provided a viable alternative to the more invasive open biopsy technique (Bergstörm, 1975; Brooks & Mercier, 1994). To this day, the muscle glycogen and exercise performance research conducted on that back of this improvement remains seminal work in the field of sports nutrition (Bergstörm *et al.*, 1967). This pattern of technology driven advances can be seen right throughout the development of sports nutrition. However, it wasn't until the 1980's that the accumulation of these developments and resulting improvements in knowledge and understanding of how nutrition could influence athletic performance ultimately led to the emergence of sports nutrition as a discipline of its own (Dunford, 2010).

Pioneered by Professor Louise Burke and Professor Ron Maughan, the field of sports nutrition has since rapidly evolved with innovations in technology continuing to punctuate major milestones in research and applied practice (Jonvik *et al.*, 2022). The last 20 years in particular has played host to the most aggressive period of growth and knowledge creation in the history of the discipline evidenced by sports nutrition research publications increasing from 211 in the year 2002 to 3,734 in 2022, a more than 17-fold increase (**Figure 1**). The majority of this research has focused solely on nutrition's impact on metabolism, physiology and physical performance, facilitating the development of more robust fuelling, recover and performance strategies (Dunne *et al.,* 2021; Jonvik *et al.,* 2022). This research data generated to date has since been compiled into multiple consensus statements on general sports, team sports, and dietary supplements (Thomas, Erdman & Burke, 2016; Maughan *et al.,* 2018; Collins *et al.,* 2020). On the back of this growing evidence base the role of the sports nutritionist is now considered an integral part of a multidisciplinary sport science and medicine athlete support team. Additionally, the number of jobs available, and third level education opportunities, have increased as professional and Olympic sporting organisations seek to employ or contract one or more sports nutritionists on either a full-time or part-time basis to "*develop, implement and monitor evidence-informed practical nutrition strategies tailored to the needs of the sport and individuals*" so as to ultimately translate the advancements in knowledge to practice (English Institute of Sport, 2022; Norwich City, 2022;). However, sports nutrition is still a relatively young, albeit rapidly evolving, discipline with many gaps in its current research base (Bentley, Mitchell & Backhouse, 2020; Jonvik *et al.,* 2022). In particular there is an opportunity for behaviour change and implementation science to aid the translation of existing knowledge to athlete behaviours as currently this remains imperfect and a reported struggle for sports nutritionists (Heaney *et al.,* 2011; Heikura *et al.,* 2017a; Heikura *et al.,* 2017b; Bentley, Mitchell & Backhouse, 2020).

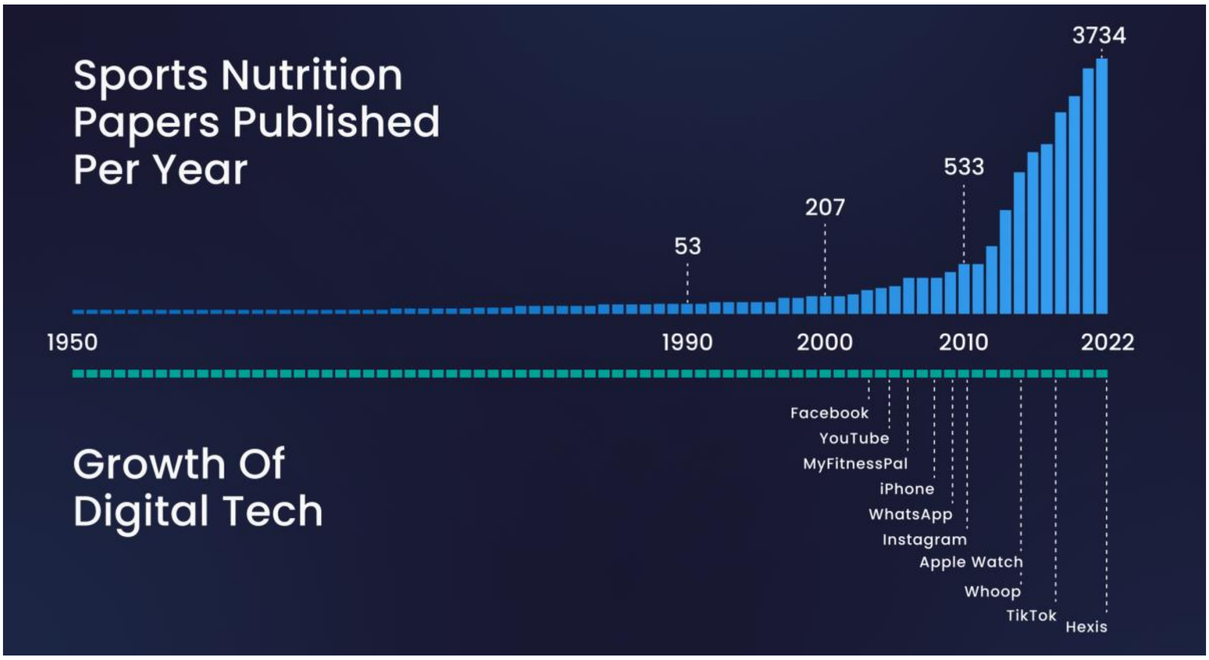


Figure 1. Sports nutrition papers published per year and parallel growth of digital technology.

In parallel to the more recent rise of sports nutrition, the emergence, popularity and uptake of smartphones and mobile apps has exploded globally (**Figure 1**), and these digital technologies have now been ubiquitously accepted as the norm (Middleton, Scheepers & Tuunainen, 2014). Today in the UK, 95% of 18-44 year olds own a smartphone and globally the number of users surpasses six billion (Ofcom, 2021; Statistica, 2022). Technology now gives its users 24/7 access to information from their pockets. How information is searched for, discovered and consumed has now changed as instant gratification is now available simply by opening an app, a quick google search or a refreshed news feed (Newman *et al.*, 2017). This on-demand information supply has created a dependence on the technology where daily usage statistics show that, on average, people in the UK spend approximately four hours a day on their smartphones and check it every 12 minutes of the waking day (Ofcom, 2018; Statistica, 2021). Interacting with mobile apps is now the primary use of smartphones globally (Data.ai, 2022). These advances in digital technology have been leveraged in more clinical settings, such as obesity management, where the use of smartphone mobile apps have been shown to be both effective and beneficial for improving nutrition behaviours and nutrition related health outcomes (Schoeppe *et al.,* 2016; De Zambotti *et al.,* 2017; Villinger *et al.,* 2019). However, this global digital breakthrough, which appears to have the ability to provide scalable and continuous nutrition support has not yet been explored in sports nutrition.

The need to understand and integrate these advancements in technology to support and enhance service provision, as well as accelerate the translation of knowledge to practice, in sports nutrition has been cited for its potential in the literature and is in need of development (Jonvik *et al.,* 2022). Given there is no such thing as an "average" athlete, personalised nutrition prescriptions in particular have been highlighted as an area of potential opportunity that is already transforming and modernising other life sciences (Thomas, Erdman & Burke, 2016; Jonvik *et al.,* 2022). Recent advancements in wearable technology, GPS and real-time monitoring have already accelerated the evolution of other disciplines within the sports science sphere, however sports nutrition has remained stagnant (Li *et al.,* 2015; Barrett, 2017; Bellenger *et al.,* 2021). The discipline is now at a critical juncture in its development where it is primed to explore how best to utilise these new technologies and avoid becoming a "laggard". These trends suggest history may be on the verge of repeating itself, however until explored further we cannot determine if this latest wave of innovation in technology may result in sports nutrition's next breakthrough.

1.2 Aims and Objectives

The aim of this thesis is to design, develop and pilot a mobile app DBCI that caters to the needs of both the athlete and the practitioner in applied sports nutrition. To this end, we aimed to utilise mixed methods, as well as behaviour change theory and design thinking methods which are considered best practices for mobile app DBCI development.

This aim will be achieved by the completion of the following objectives:

a) To explore how social media mobile apps are being used by sports nutritionists as part of their service provision to athletes, as well as capture their experiences and opinions of its use. This aim will be achieved in Study 1 and will be used in subsequent chapters to determine the practitioner considerations in the development of a mobile app digital intervention.

b) To explore athletes' experiences and opinions of communication strategies in applied sports nutrition, as well as their suggestions for future mobile app supportive solutions. This aim will be achieved in Study 2 and will be used in subsequent chapters to determine the athlete considerations in the development of a mobile app digital intervention.

c) To explore the design and pilot of an industry specific mobile app DBCI designed using a Behavioural Design Thinking approach. This aim will be achieved in Study 3 and the findings will be further discussed for their implications on sports nutrition service provision.

1.3 Structure of Thesis

Building on this introduction in chapter one, the thesis progresses in chapter two to review the literature surrounding mobile app digital interventions, behaviour change, design thinking and current methods of practitioner led sports nutrition support, before going on to discuss the methodological approaches used in this thesis. Chapters three, four and five each report on the studies that make up the original research component of this body of work. Each of these chapters is comprised of an introduction, methods, results, and discussion section. Chapter six synthesises the findings of these three studies for a general discussion before affirming the main findings and making suggestions for future research to keep this novel area of the sports nutrition discipline advancing in the right direction.

Chapter Two:

Literature Review and General Methods

This chapter provides an overview of the current evidence base and presents the methodologies used within this thesis. Where required, more specific details are also presented in the subsequent chapters.

2.1 Background

This section will introduce the current status quo in applied sports nutrition whilst identifying the present known factors that influence athletes' nutritional behaviours. Given the overall aim of this thesis is to develop and pilot a mobile app digital intervention that caters to the needs of both the athlete and the practitioner in applied sports nutrition, the literature review progresses to explore mHealth interventions from more clinical fields of practice, considering both the patient and the practitioner in the process. Building on this, the current opportunities for technology to advance sports nutrition described in the literature are presented. Consideration is also given to the evidence base surrounding behaviour change theory and design thinking frameworks. To conclude the section, methodological and paradigmatic positions are addressed, outlining how this thesis and its individual studies are embedded within an overarching paradigm.

2.2 Factors Influencing the Nutritional Behaviours of Athletes

Athletes are a unique population with specialised dietary needs based on the physiological demands of their sport (Thomas, Erdman & Burke, 2016; Burke & Hawley, 2018). Periodising dietary intake to meet individual nutrient requirements is important for optimal health and can support an athlete's ability to perform during, recover from and adapt to training and competition events (Jeukendrup, 2017; Impey *et al.*, 2018; Stellingwerff, Morton & Burke, 2019). Despite evidence to suggest that athletes may have sufficient nutrition knowledge, the translation into an athlete's nutritional behaviours and adherence remains a challenge (Cole *et al.,* 2005; Spronk *et al.,* 2014; Tam *et al.,* 2019). Instead, what an athlete chooses to eat and drink has been shown to be a dynamic, complex and continually changing process (Birkenhead & Slater, 2015). This dynamic nature and complexity can be illustrated by the work of Wansink and Sobal (2007) who demonstrated that individuals can, on average, make in excess of 220 food-related decisions a day. Furst and colleagues (1996) suggest a conceptual model of an individual's food choice process that integrates the influences of their past experiences, ideals (e.g. expectations and beliefs), personal factors (e.g. preferences and health) and resources (e.g. skills and knowledge) as components of a 'personal food system' that is used to make final nutrition behaviour decisions. However, despite it being suggested that many of the influences that are applicable to the nutrition behaviours of the general population are also relevant to athletes (Stok *et al.*, 2017; Pelly, Thurecht & Slater, 2022), it has also been recommended to better understand the specific complexities related to an athlete's nutrition behaviours so as to improve the targeting of interventions that can lead to their improved dietary intake (Bentley *et al.*, 2019).

A review conducted by Birkenhead and Slater (2015) suggested that the nutrition behaviours of athletes can be influenced by physiological (e.g. fat-free mass and resting metabolic rate), psychological (e.g. body image), social (e.g. marketing), and economic (e.g. cost) factors and can vary both within and between individuals. More recently this list of factors has been expanded to include the influence of cultural background (e.g. food beliefs), health and nutrition perceptions (e.g. nutritional content), sport and stage of competition (e.g. season/phase), as well as situational (e.g. routine), and interpersonal (e.g. peers) factors (Pelly, Thurecht & Slater, 2022). However, from the research conducted to date in athletes it appears that performance and competition is one of the most important factors that influences their nutrition behaviours (Smart & Bisogni, 2001; Robbins & Hetherington, 2005; Long *et al.*, 2011; Pelly, Burkart & Dunn, 2017, Bentley *et al.*, 2019). Given the periodised nature of the sporting calendar year (e.g. pre-season, in-season, off-season), athletes have self-reported seasonality in their own nutritional behaviours that align with the phase of year and it's perceived importance (Bentley *et al.,* 2019). These nutrition behaviours have been observed in both individual (Robbins & Hetherington, 2005) and team (Smart & Bisogni, 2001) sport settings. Although it has been highlighted that power and skill-based athletes place less importance on factors that influence performance, such as their fuelling and recovery food choices, than those in endurance sports (Smart & Bisogni, 2001; Robbins & Hetherington, 2005; Pelly, Burkart & Dunn, 2017). Additionally, a cyclic relationship between performance, emotions and food has been described in the literature to illustrate the decreasing motivation of performance as a driver of nutritional behaviours in athletes if their performance was not going to plan (Bentley *et al.,* 2019).

Athletes have suggested that practical resources such as food plans may positively impact their nutrition behaviours by providing them with confidence, structure and routine (Bentley *et al.,* 2019). Despite these plans being identified as enablers to positive nutrition behaviours, the same research also identified that athletes lack the skills required to develop these resources and suggest that this inability is a result of not having sufficient opportunities to develop this competency, as well as a desire for someone else to do it on their behalf. The suggestion put forward by athletes has been corroborated by behaviour change research in more general settings where the process of action planning has been shown to be a factor that can provide a cue for the desired behaviour(s), thus aiding the development of structure and routine (Michie *et al.,* 2013); and coming from a credible source, e.g. the sports nutritionist, can positively influence an individual's attitudes towards and beliefs about the behaviour, consequently providing them with more confidence (Human Behaviour Change Project, 2016). However, plans are specific to goals (Bailey, 2019) and therefore the alignment of goal setting for an athlete, e.g. identifying an appropriate performance focus, and action planning, e.g. the creation of a plan, appears to be important factors that may influence the nutritional behaviours of athletes.

2.3 Current Status of Behavioural Interventions in Sports Nutrition

Historically, research efforts in the sports nutrition discipline have focused on investigating nutrition's impact on metabolism, physiology and physical performance to develop the knowledge and evidence-base underpinning good practice (Burke *et al.*, 2018; Jeukendrup, 2017). Despite these improvements in knowledge and underpinning science, it has been suggested that the research becomes meaningless if the athlete community do not adopt and implement the findings into their daily nutritional practices (Bentley, Mitchell & Backhouse, 2020). To illustrate, the period of 2002-2022 has been host to the most significant surge in sports nutrition publications to date (see **1.1**); notwithstanding this increase in knowledge, athlete's non-adherence to the sports nutrition guidelines is frequently reported (Krempien & Barr, 2011; Heikura *et al.,* 2017; Bentley *et al.,* 2021). A fundamental role of the sports nutritionist has been to use this evidence-base to educate athletes (Birkenhead & Slater, 2015) with the expectation that greater knowledge will lead to improved nutritional behaviours (Parmenter & Wardle, 1999). However, a systematic review exploring the effectiveness of nutrition education programs in athletes only reported a weak positive correlation between an athlete's knowledge and their nutrition behaviours (Heaney *et al.,* 2011). This mismatch between athletes nutritional behaviours and existing knowledge has been highlighted by Heikura and colleagues who demonstrated that although a group of elite male and female runners and race walkers had sufficient knowledge of how to appropriately periodise their dietary intake in line with contemporary sports nutrition guidelines to support the demands of training and competition performance (Heikura, Stellingwerff & Burke, 2018), the majority did not adhere (Heikura *et al.,* 2017). This lack of knowledge translation into nutritional practices and behaviours in athletes suggests that despite the discipline's efforts with education, it alone is insufficient to influence change (Atkins & Michie, 2013; Kelly & Barker, 2016; Atkins *et al.,* 2017; Bentley *et al.,* 2021).

As the link between knowledge and behaviour has been shown to be equivocal (Heaney *et al.,* 2011), it has been suggested that more multifaceted and theoretically driven behaviour change interventions need to be designed and delivered, where education may be one component of a more comprehensive strategy (Atkins & Michie, 2013). However, to date there has only been a very limited number of such implementation science driven behaviour change interventions in sports nutrition (Abood, Black & Birnbaum, 2004; Doyle-Lucas & Davy, 2011; Costello *et al.,* 2018). A recent review by Bentley and colleagues (2020) revealed that only three studies in sports nutrition mentioned the use of theory. A different theoretical model was used for each of the studies identified, these included the Social Cognitive Theory, Health Belief Model and the Behaviour Change Wheel. The same research also highlighted that the most commonly used behaviour change techniques (BCTs) in sports nutrition interventions were providing "instruction on how to perform the behaviour" and "information about the health consequences", although these techniques were found in both effective and in-effective interventions, reiterating sports nutrition's uncertainties of how to best implement behaviour change strategies. In total, 19 BCTs were currently found to be employed within sports nutrition interventions, suggesting that 80% of the available BCTs are not being used (Michie *et al.,* 2013). Compared with physical activity research where there is a more well-stablished use of theory to inform intervention design, this volume of BCTs used in sports nutrition is considerably narrower (Cradock *et al.,* 2017) and also has noticeable absentees such as "action planning" which plays an important role in self-regulation, a cornerstone of several behaviour change theories (Rosenstock, Strecher & Becker, 1988; Bandura, 1991).

Sports nutritionists have acknowledged that many athletes struggle to adhere to the desired nutrition behaviours because they lack the memory, attention, decision-making and organisational skills necessary (Bentley *et al.*, 2019). The same group of nutritionist participants in Bentley and colleagues (2019) research who recognised these deficits sought to address them by introducing solutions that made adherence as easy as possible for athletes by removing the need for thought and planning. However, this approach treats the symptoms but not the cause of the behaviour and presents no development opportunities for athletes to learn and improve (Collins & MacNamara, 2012). Paradoxically, such approaches have been shown to dampen feelings of autonomy and self-efficacy, as well as undermine an individual's sense of personal responsibility to make decisions (Deci & Ryan, 2008). Based on the literature to date it appears that these "make it as easy as possible" athlete-centred interventions may in fact be detrimental when it comes to subsequent adherence to desired nutritional behaviours. Overall, it seems that behavioural interventions in the discipline of sports nutrition are in their infancy and require more development to specifically address the complex interplay of the various enabling and inhibiting factors that may influence an athlete's nutritional behaviours (Bentley *et al.*, 2019; Bentley, Mitchell & Backhouse, 2020).

2.4 Opportunities for Technology to Advance Sports Nutrition

Most paradigms in sports nutrition have been established under laboratory conditions (Bergstörm *et al.*, 1967; Pasiakos *et al.*, 2013) before being extrapolated to fit in situ nutrition recommendations (Mujika & Burke, 2010; Thomas, Erdman & Burke, 2016). Despite the wealth of knowledge produced via these controlled methods, there are limitations in the ecologically validity of the results and recommendations generated (Jonvik *et al.,* 2022). However, recent advances in mobile technologies, wearable devices and real-time monitoring have enabled the ability for physiological data to be captured anywhere at any time (Bellenger *et al.,* 2021) contributing to a shift in research from the traditional laboratory environment to more ecologically valid field settings (Bellenger *et al.,* 2022). It has been demonstrated that this data can also be used to provide tailored real-time feedback to the individual (Van Hooren *et al.,* 2019). Embracing these technology improvements and trends in their integration (Dellaserra, Gao & Ransdell, 2014) provide significant opportunities for sports nutritionists to enhance the speed, efficiency and scale of tailored nutrition intervention delivery (Jonvik *et al.,* 2022). The uptake of these advancements has already commenced in other sport science disciplines (Peart, Balsalaobre-Fernández & Shaw, 2019). A recent example includes the use of a smartwatch application worn by athletes competing in the 10,000 metre, marathon and race walk events at the 2020 Tokyo Olympics (Muniz-Pardos *et al.,* 2021). The data captured was used to characterise physiological and thermal strain experienced by the athletes during the events and contribute to more timely and accurate diagnosis in the instance of medical emergencies. These technologies have also been cited for their ability to estimate exercise energy expenditure from session type, intensity and duration data (Keytel *et al.,* 2005), although the accuracy and acceptability of these predictions remains poor currently (Germini *et al.,* 2022). However, the application of machine learning techniques to wearable device derived exercise energy expenditure estimates have demonstrated significantly lower error rates (O'Driscoll *et al.,* 2020) and may offer a more reliable means to capture the energy cost of free-living activities. In addition to wearable devices and mobile apps, entire digital ecosystems have been developed to improve the quality and accuracy of dietary energy intake data capture methods (Ferrara *et al.,* 2019). The combined efforts of advancements in free-living exercise energy expenditure, energy intake data capture and real-time feedback has been cited for its potential to help mitigate against unresolved issues in the field of sports nutrition such as relative energy deficiency in sport (RED-S) (Mountjoy *et al.,* 2018; Jonvik *et al.,* 2022).

Given there is no such thing as an "average" athlete, position stands recommend personalised nutrition strategies tailored to the individual athlete that take into account the specificity and uniqueness of the individual (Thomas, Erdman & Burke, 2016). More recently, the use of technology to aid the generation and delivery of such personalised nutrition prescriptions, over longer periods of time and without the associated human labour and time costs, has been identified as an opportunity for the field of sports nutrition (Jonvik *et al.,* 2022). Given the limited time and resources, or "stretched service", sports nutritionists report experiencing (Bentley *et al.,* 2019), mobile enabled technology may offer practitioners an opportunity to deliver such personalised prescriptions at scale (Villinger *et al.,* 2019). Despite the opportunities technology presents, its use may also be a potential source of stress (Anderson, Langstrup & Lomborg, 2020), albeit this remains undetermined in athlete populations. To limit potential barriers to the integration of new technologies in athlete populations collaborations between researchers and practitioners, as well as with the athlete and the coach have been recommended (Bartlett & Drust, 2021). Additionally, the inclusion of behaviour change science is recommended to aid the impactful implementation of these innovations (Bentley, Mitchell & Backhouse, 2020).

2.5 Behaviour Change Theory and the COM-B Model

Recognising that education alone is insufficient to influence significant changes in athlete's nutrition behaviours (Heaney *et al.,* 2011), sports nutritionists have identified the need for more work focusing on behaviour change interventions in applied practice (Bentley, Mitchell & Backhouse, 2020; Dunne *et al.,* 2021). Behaviour change interventions can be defined as a coordinated set of activities designed to change specified behaviour patterns (Michie, van Stralen & West, 2011), where the use of, as well as contents contained in, mobile technology may be one of the several activities. Such interventions have been recommended by the UK Medical Research Council (Craig *et al.*, 2008), where the importance of a detailed description of the components of the intervention has been highlighted (Michie *et al.*, 2008). Specifically, a "Template for Intervention Description and Replication" (TIDieR) allows for a systematic description of the intervention (Hoffmann *et al.*, 2014). These theory driven behaviour change interventions have been shown to be more effective at changing behaviour than non-theory approaches (Michie & Prestwich, 2010). Despite this many interventions are often designed with no theoretical underpinning whatsoever, contributing to ineffectiveness or in some instances failure (Michie, van Stralen & West, 2011; Eccles *et al.*, 2012).

There are numerous behaviour change theories on which an intervention can be modelled. Many of these theories share similar and overlapping constructs, however, are named differently (Michie, Atkins & West, 2014). It can be challenging for researchers to identify an appropriate and valid theory for the context of their project given the array of choices. Many researchers have opted for the "most-often-used" theories leading to a smaller number dominating the evidence base (Painter *et al.*, 2008). A scoping review by Davis and colleagues (2014) explored 276 research articles and discovered that of the 82 theories identified, just four theories accounted for 174 (63%) of the articles. The four most frequently used theories were the Transtheoretical Model of Change (Prochaska & Velicer, 1997), the Theory of Planned Behaviour (Azjen, 1991), Social Cognitive Theory (Bandura, 1986) and the Information-Motivation-Behavioural-Skills Model (Fisher & Fisher, 1992). However, despite their use many of these theories have been widely criticised. For example, the Transtheoretical Model of Change, which posits that health behaviour change evolves through six stages (precontemplation, contemplation, preparation, action, maintenance and termination), has been critiqued for its rigidity between stages and a lack of consideration for the impulsive human nature of relapse (West, 2005; Cahill, Lancaster & Green., 2010). Similarly, Social Cognitive Theory, which emphasises the dynamic interaction between the person, their environment and their behaviour, has been criticised for its inadequacy in explaining the variations in complex human behaviour, as illustrated by its heavy reliance on reflective cognitive processes and largely ignored automatic processes (Coulson *et al.,* 2016). Additionally, these theories focus primarily on the intra-individual variables that may impact behaviour and often fail to consider the impact of wider social and environmental factors (Glanz & Bishop, 2010). These factors are important considerations for sports nutritionists and researchers in the discipline as athletes' nutrition behaviours are part of a dynamic system embedded within their social and physical environments (Bentley *et al.,* 2019; Pelly, Thurecht & Slater, 2022). To overcome these shortcomings of previous behaviour change theories, Michie and colleagues (2011) developed a "behaviour system" called the COM-B model (**Figure 2**) which was based on nineteen existing behaviour change intervention frameworks identified via systematic review. This modern meta-theory was intended to be comprehensive and applicable to all behaviours and was developed to address any shortcomings of previous behaviour change theories (Jackson *et al.,* 2014). Given the strength and breadth of the COM-B model it was identified as the most appropriate theoretical underpinning for this thesis where it is described in more detail in the following paragraphs.

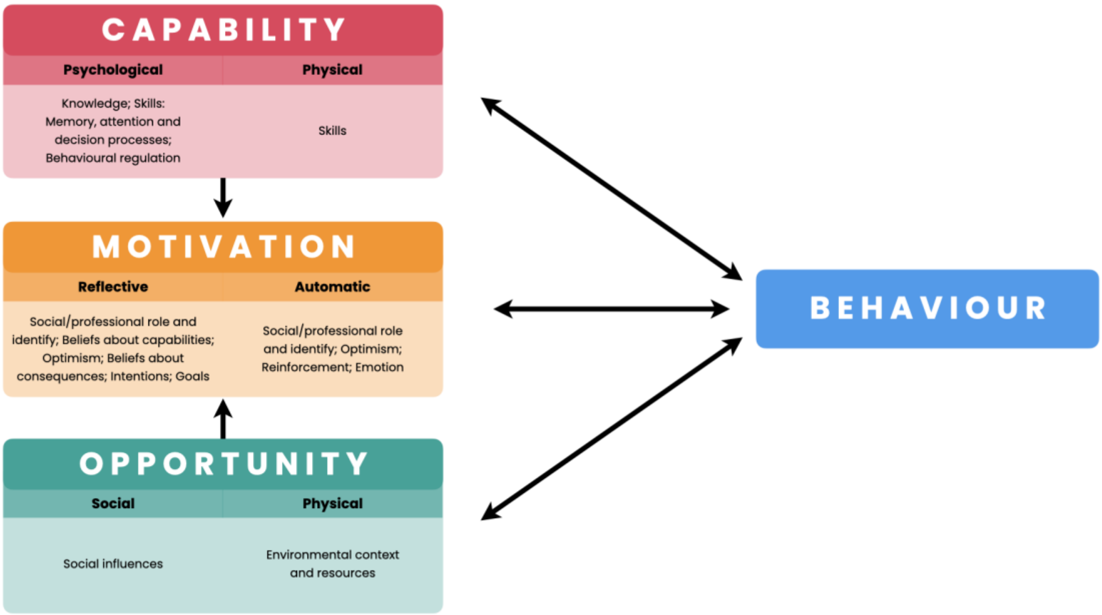


Figure 2. The COM-B model mapped to the theoretical constructs of the TDF (Michie, van Stralen & West, 2011; Cane, O'Connor & Michie, 2012).

The COM-B model proposes that for an individual to engage in the desired behaviour (B) they need the capability (C), opportunity (O) and motivation (M), and these COM components interact to generate the behaviour which in turn can also influence these components themselves, as denoted by the single and double headed arrows in **Figure 2**. Capability is defined as the individual having the psychological (e.g. knowing what to do) and physical (e.g. having the technical skills) capacity to engage in the desired behaviour. Opportunity is defined as all of the factors that lie outside the individual that make the behaviour possible or prompt it, such as an individual's physical opportunity (e.g. having access to the resources required) and social opportunity (e.g. the environment, people and culture around them). Motivation is defined as all those brain processes that energise and direct behaviour, which may be automatic (e.g. habitual processes and emotional responses) and reflective (e.g. analytical decision-making) in nature. These individual components of the COM-B model can be further elaborated into specific constructs using the theoretical domains framework (TDF) (Cane, O'Connor & Michie, 2012). The COM-B model itself is a component layer of a three-tiered classification system called the "behaviour change wheel" (BCW) (**Figure 3**) (Michie, van Stralen & West, 2011).

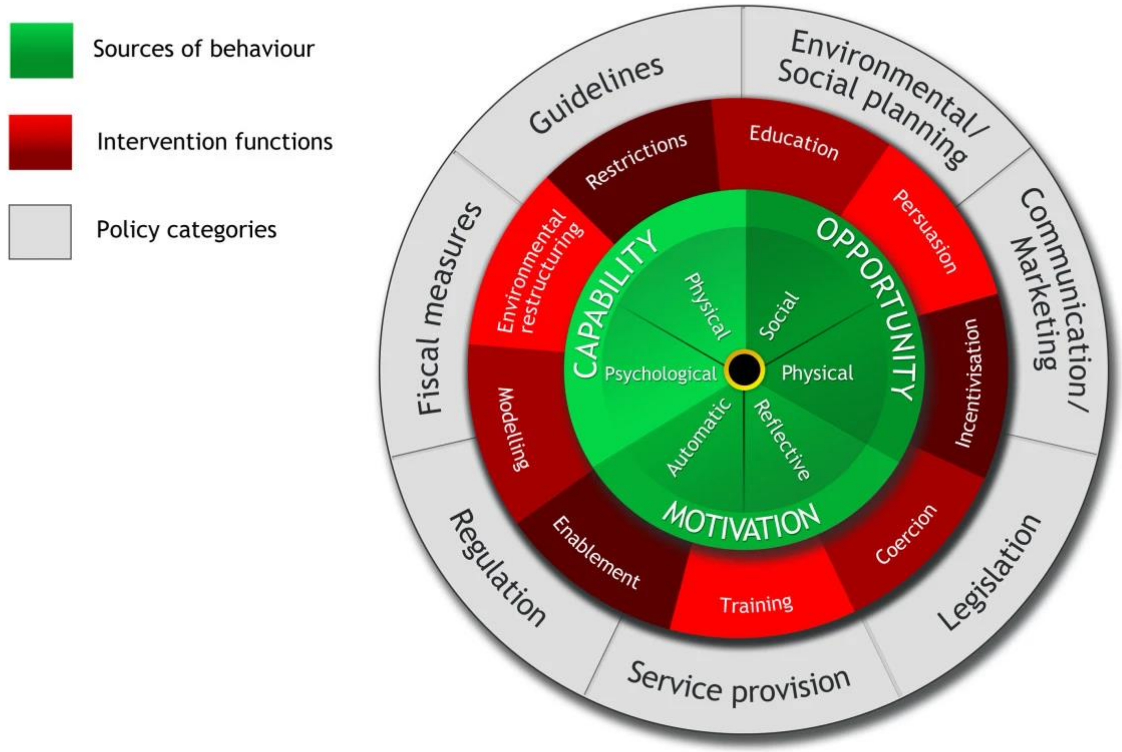


Figure 3. The Behaviour Change Wheel (Michie, van Stralen & West, 2011).

Positioned around the COM-B core of this classification systems is an intervention function layer which is comprised of nine broad categories of means by which an intervention can change a behaviour. These intervention functions include education, persuasion, incentivisation, coercion, training, restriction, environmental restructuring, modelling, and enablement. A matrix of explicit links between capability, opportunity and motivation and the nine intervention functions (**Figure 4**) illustrate which functions are likely to be effective in bringing about the desired change in behaviour (Atkins & Michie, 2015). The final outer layer of the BCW is comprised of seven policy categories that could enable those intervention functions to occur. The seven policy categories include: legislation, service provision, regulation, fiscal measures, restrictions, environmental/social planning, and communications/marketing. Definitions and examples of the intervention functions and policy categories can be seen in **Table 1**

Table 1. Definitions of BCW Intervention Functions and Policy Categories (adapted from Michie, van Stralen & West, 2011).

Intervention Function	**Definition**	**Examples**
Education	Increasing knowledge or understanding	Providing information to promote adequate fuelling
Persuasion	Using communication to induce positive or negative feelings to stimulate action	Using imagery and/or success stories to motivate improvements in fuelling and recovery
Incentivisation	Create expectation of reward	Using rewards for practicing desired behaviours
Coercion	Creating expectation of punishment or cost	Fining athletes for not adhering to recovery protocols
Training	Imparting skills	Cooking lessons to improve meal preparation skills
Restriction	Using rules to reduce the opportunity to engage in target behaviour to be changed (or vice-versa)	Prohibiting takeaways from scholar athletes' digs
Environmental Restructuring	Change the physical or social context	Provide on screen prompts for athletes to refuel post training
Modelling	Providing an example for people to aspire to or imitate	Using senior athletes as role models for academy athletes to imitate
Enablement	Increasing means / reducing barriers to increase capability or opportunity	Using a mobile app to provide behavioural support for nutritional periodisation
Policy Category		
Communication/Marketing	Using print or digital media	Conducting mass media campaigns
Guidelines	Creating documents that recommend or mandate practice	Producing and disseminating nutrition plans
Fiscal	Increasing or reducing the financial cost	Increasing duty or providing discounts
Regulation	Establishing rules or principles of behaviour or practice	Establishing and agreeing required practices
Legislation	Making or changing laws	Prohibiting certain practices
Environmental/Social Planning	Controlling the physical or social environment	Using training centre planning

Service Provision	Delivering a service	Establishing support services in the workplace/industry

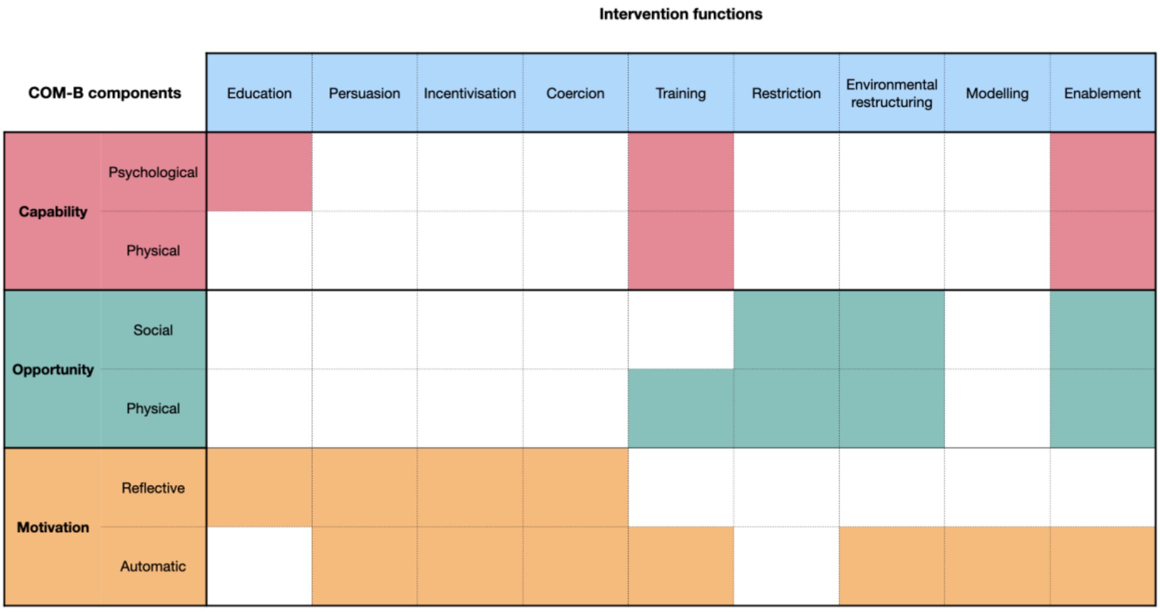


Figure 4. Matrix of links between COM-B components and intervention functions (Atkins & Michie, 2015).

The design and development of a theoretically informed behavioural intervention using the COM-B and BCW systems is typically a three-stage process, with each section have additional sub-processes (Michie, van Stralen & West, 2011). This systematic process has been referred to as behavioural design (Vooheis *et al.*, 2022). In stage one interventions designers are required to "understand the behaviour" by: 1) defining the problem in behavioural terms, 2) selecting a target behaviour, 3) specifying the behaviour targeted for change, and 4) identifying what needs to change. Typically, the COM-B model and the TDF are used in conjunction with each other to help the intervention designer understand why behaviours are the way they are and identify what needs to shift for the desired behaviour to occur. Stage two involves "identifying the intervention options" that may help change the desired behaviour. This stage can be aided by using the matrix of explicit links between COM-B components and intervention functions before policy categories are selected. Stage three is the final stage and requires the interventions designer to "identify implementation options" and specific resources to populate the intervention functions with. Intervention designers bring the intervention functions to life using behaviour change techniques (BCTs) which are often referred to as the "active ingredients" of an intervention (Michie *et al.,* 2013). At this stage, more recent tools have been developed to complement the COM-B and BCW systems such as the Theory and Techniques Tool that can be used by intervention designers to identify effective BCTs based on their proposed mechanism of action (MOA), triangulated links and expert consensus (Human Behaviour Change Project, 2016; Michie *et al.,* 2017).

The COM-B and BCW systems have been successfully applied to the development of patient and practitioner supportive mobile technologies across a range of healthcare contexts including gestational diabetes management (Handley *et al.,* 2015), vegetable intake in young adults (Nour, Chen & Allman-Farinelli, 2019) and smoking cessation (Fulton *et al.,* 2016). However, to date there has been no application of the COM-B and BCW systems to inform the development of sports nutrition specific mobile technologies. However, there has been some application of the COM-B and BCW in a practitioner led sports nutrition intervention in a professional rugby league academy (Costello *et al.,* 2018). In the context and structure of this present thesis, both the COM-B and BCW systems will be used in conjunction with design thinking methodologies (see **2.7**) to synthesise the results from Study 1 and Study 2 and aid the development of a sports nutrition specific mobile app intervention.

2.6 Digital Behaviour Change Interventions and mHealth

Few sports nutritionists have been trained to design, develop and deliver effective interventions targeting the nutrition behaviours of athletes (Bentley, Mitchell & Backhouse, 2020), and significantly increasing the number of skilled practitioners would be time consuming and costly (Dietz *et al.,* 2016). Additionally, many of the opportunities for supporting behaviour change occur outside of typical scenarios in which an athlete will engage with a sports nutritionist, e.g. at the athletes home. Fortunately, the proliferation of digital technologies provides sports nutritionists with an opportunity to deliver organisation wide behavioural interventions that can support nutrition behaviours across a broad spectrum of settings (Craig *et al.,* 2020). Such an intervention that employs a digital technology specifically for the modification of a behaviour to maintain and improve health, and in the instance of sport also support and enhance performance, is referred to as digital behaviour change interventions (DBCI) (Michie *et al.,* 2017). As well as more in situ intervention delivery, DBCIs provide practitioners with the opportunity to understand the dynamics of behaviour by continually collecting real-time data in an unobtrusive manner via smartphone apps, wearable devices and other internet connected platforms (Craig *et al.,* 2020). The term mHealth was coined in 2008 to describe this new industry vertical of mobile phones performing healthcare tasks (Gerber *et al.,* 2010). The World Health Organisation (2015) define mHealth as "the provision of health services and information via mobile mobiles". To date, the use of DBCIs in the mHealth apps has been absent from the field of sports nutrition and instead predominately focused on more clinical fields of practice, such as obesity prevention and management (Stein & Brooks, 2017), physical activity (Adams *et al.,* 2013) and adherence to treatments (Chandler *et al.,* 2019).

The delivery of DBCIs via mHealth apps has demonstrated significant benefits to both the patient and the practitioner in these clinical settings (Rowland *et al.,* 2020) where it is now estimated that more than 50 million people worldwide use a mobile app based self-triage (Millenson *et al.,* 2018). For the healthcare practitioner, specific benefits can that mHealth DBCIs can bring include increasing efficiency, reducing costs, and providing the required healthcare in the least time possible with the minimum number of risks (Ventola, 2014). Additionally, platform functionalities such as operative planning, diagnostic support, education, and follow up management have been identified as facilitators of these benefits (Baniasadi *et al.*, 2018; Hamilton *et al.,* 2018; Zahmateshan *et al.,* 2021). These described benefits could have significant impacts on the effectiveness of the sports nutritionist, however their use of technology to support practice has yet to be explored. For the patient, specific benefits can include improvements in speed and accuracy of diagnosis, personalised treatment regimes, improved access and continuous support (Rowland *et al.,* 2020). However, the desire for such technologies in athletes is not yet known. Although it has been suggested that end-user involvement, e.g. the athlete, in the development of mHealth DBCIs is essential to design user-centric features that meet their demands, as well as those of the behaviour change requirements of the intervention (Yardley *et al.,* 2016).

2.7 Design Thinking and Innovation

Design has always been a catalyst for the innovation processes in product and service development (Tschimmel, 2012). As a way of thinking, design was first mentioned by Nobel Prize winner Herbert Simon in his book “The Science of Artificial” (1969). More recently, the importance and value of design thinking as a tool for innovation has been recognised by both businesses, for example Apple, Samsung and Dyson, as well as government (Gruber *et al.,* 2015). Design thinking itself is a human-centred approach to innovation that puts the observation and discovery of often highly nuanced, even tacit human needs right at the forefront of the innovation process, whilst also considering the possibilities of technology, and the sociocultural system context (Gruber *et al.*, 2015). A systematic design thinking innovation process has been developed by the Hasso Plattner Institute of Design, the d.school, at Standford University (2010). This five step process prioritises empathy as its first step before defining the problem, ideating concepts and potential solutions, prototyping to think and learn, and finally testing of the developed solution (**Figure 5**). The first step, empathise, is the centrepiece of the human-centred design process seeking to understand the end-user of the product or service within the context of the design challenge. Step two, define, focuses on bringing clarity to the design space based on the designer's learnings from step one. Step three, ideate, concentrates on idea generation and provides both the fuel and the source material for developing prototypes and getting innovative solutions into the end-user's hands. Step four, prototype, is the iterative generation of artifacts intended to answer questions that get the designer closer to the final solution. The final step, test, is when the designer solicits feedback about the prototype from the end-user.

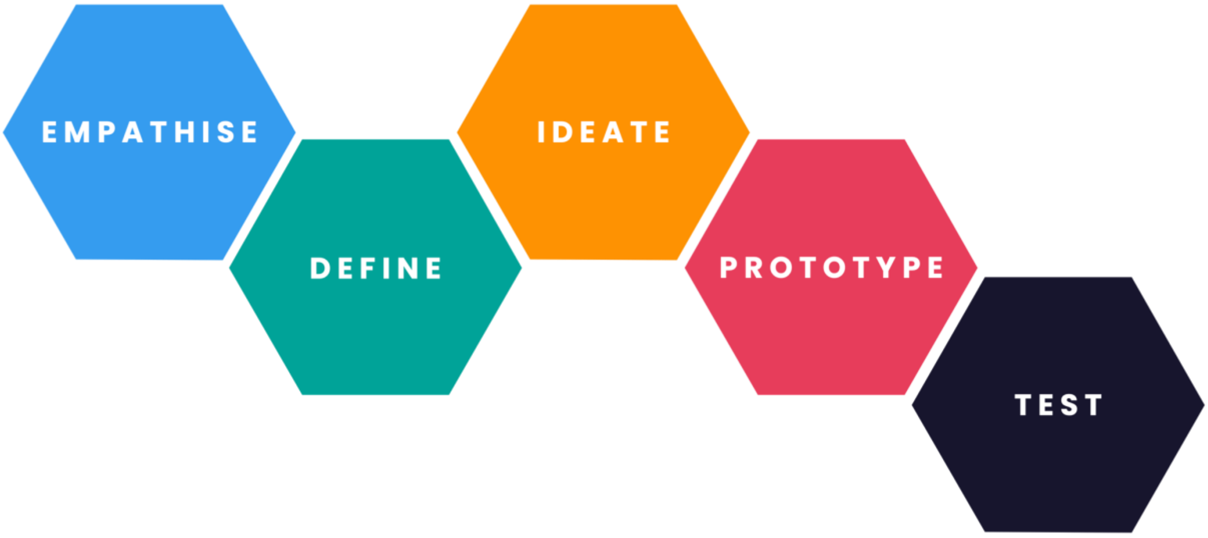


Figure 5. Design Thinking Process Guide (Hasso Plattner Institute of Design, 2010).

The design thinking process is quite contrasting to the practises of applied sports practitioners who are conditioned to start designing athlete interventions often grounded in the "nuts and bolts" of the profession, such as numbers, principles, and scientific rationale (Buchheit & Allen, 2022). These pre-formed practitioner hypotheses are not as conducive to the development of novel and unconventional solutions (Lawson, 2005). Additionally, many scientists that have been designing interventions throughout their careers, often are not aware that they are performing a design process (Braha & Maimon, 1997). In this way, the use of design thinking in the context of sports nutrition offers a new and formalised approach to tackle complex problems in which existing practice paradigms may not be optimal, or may even require a whole new approach (Roberts *et al.,* 2016).

2.8 Behavioural Design Thinking

Numerous similarities and differences between the approaches used in behavioural design and design thinking have recently been discussed by domain experts from the UK government's Behavioural Insights Team and Harvard University (Hallsworth & Kirkman, 2020; Tantia, 2021). To illustrate, Design Thinking relies on end-user preferences, needs and recommendations to iteratively build interventions, the focus is on producing creative solutions that users will enjoy and regularly engage with (Roberts *et al.,* 2016; Grau & Rockett, 2022). In contrast, behavioural design focuses on theory and evidenced based linkages to understand the behavioural problem, select the intervention content and implement the designed solution, which is rigorously tested against its ability to effect behaviour change, but not necessarily how and whether the end-users are engaging (Michie, van Stralen & West, 2011). However, both solutions emphasize the underpinning importance of understanding and diagnosing the problem prior to designing and delivering a solution. Given the complimentary nature of both approaches it has been suggested that the best practices from both behavioural design and design thinking be amalgamated to develop more effectively engaging DBCIs (Short *et al.,* 2015; Perski *et al.*, 2016; Yardley *et al.,* 2016). A recent scoping review sought to identify, map and synthesise how the best practices from both behavioural design and design thinking can be integrated throughout the mHealth DBCI design process (Voorheis *et al.,* 2022). All 75 primary studies included in the review were published between 2012 and 2021, with a surge from 2018 onward accounting for 68% of the research and highlighting the innovative and rapidly evolving mHealth DBCI landscape. The authors identified the most notable ways in which both practices were used together to consolidate a novel approach for mHealth DBCI design referred to as "Behavioural Design Thinking".

This interdisciplinary collaboration that breaks down the silos between the two fields is a five-step process (**Figure 6**) (Voorheis *et al.*, 2022). Step one focuses on empathising with the users whilst simultaneously conceptualising their behaviour change needs. During step two the intervention designer defines the user and behaviour change requirements. Step three involves ideating user-centred features and behaviour change content for the intervention. Step four prioritises prototyping a solution that is user-centric and supports behaviour change. The final step, step five, tests the solutions against user needs and for its behaviour change potential.

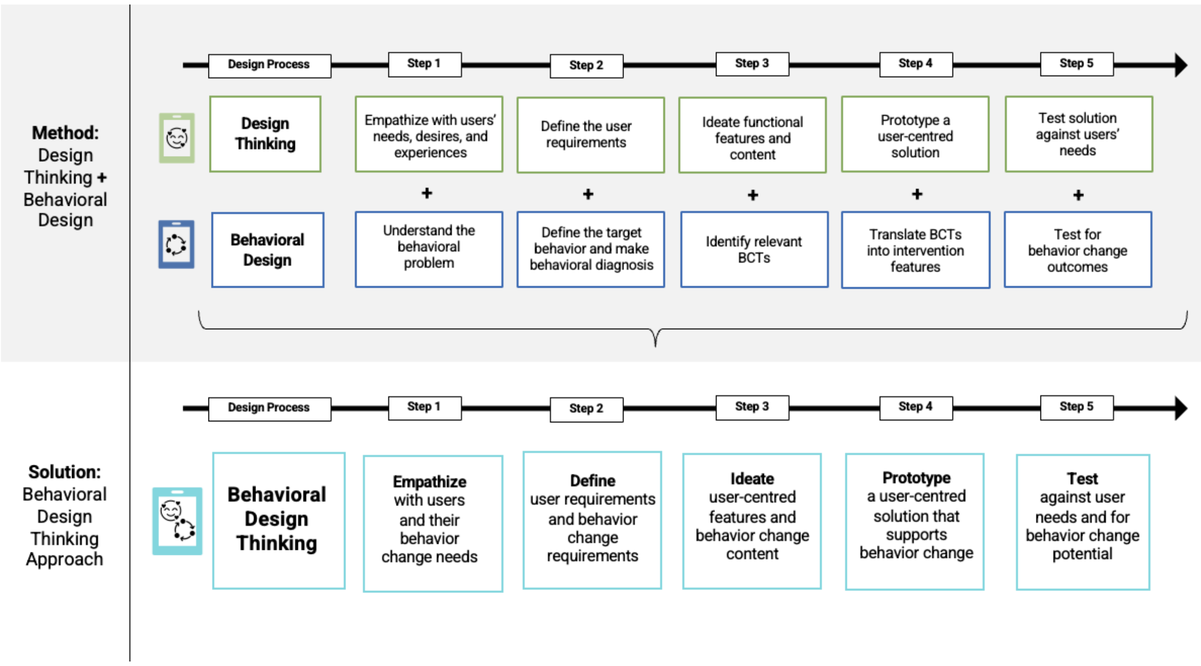


Figure 6. A Behavioural Design Thinking approach to mHealth DBCI design (Voorheis *et al.*, 2022).

2.9 Framing the Research: Research Paradigms and Methodologies

Building on the previously outlined conceptual opportunities and theoretical frameworks that run through this thesis, it is now pertinent to discuss the paradigmatic underpinning of this body of research. Given this, the following section (**2.10**) will first introduce the high-level paradigms of quantitative research, qualitative research, mixed-methods research, and pragmatism. Once introduced, the proceeding section (**2.11**) will explain the methodological approaches of innovation research and how this current thesis is embedded in its principles.

2.10 Qualitative, Quantitative and Mixed Methods Research

Sports nutritionists, like many other decision makers, are often faced with complex questions in their practice, which both qualitative and quantitative research can help them answer. Both methods differ significantly in terms of how data is collected and analysed (Gelo, Braakmann & Benetka, 2008). However, despite being fundamentally different and well-established methodological approaches to research, there is no unanimously agreed upon definition of either (Sparkes & Smith, 2014). Quantitative research focus on the "measurement and analysis of casual relationships between variables, not processes" as phenomena that are reduced to numerical values in order to carry out statistical analysis (Denzin & Lincoln, 1994). In contrast, qualitative research is concerned with the "intimate relationship between researcher and topic, and the situational constraints that shape the enquiry" (Denzin & Lincoln, 1994), and has an emphasis on non-numerical data such as audio recordings and transcripts (Burnard *et al.*, 2008). No single method can provide a complete understanding of complex and dynamic behaviour (Gill, 2011). Given this both methods are often placed in opposition with each other and get defined by what each is not, instead of what they are (Sparkes & Smith, 2014). This dualism induced dichotomy, similar to mind-body, sport-exercise and nature-nature, can oversimplify complexity and does not help our understanding of reality (Gill, 2011). Despite this, acknowledging the differences between both methods, as well as what each type of research has to offer and the value it brings when compared to the other, are important considerations for the disciplines within sports and exercise science (Martin, 2011).

Traditionally, research within the sports and exercise sciences disciplines, including sports nutrition, has taken a positivist approach (Sparkes, 1998; Atkinson, 2012) and primarily focused on quantitative research to identify casual effects and associated levels or reliability for the provision of evidence-based advice for athletes, coaches and organisations (Ronkainen & Wiltshire, 2019). Positivists adhere to the view that phenomena, such as human behaviour, has an objective reality where the relationships between variables can be measured and analysed, which in turn allows prediction (Gelo, Braakmann & Benetka, 2008; Park, Konge & Artino, 2010). By contrast, constructivism considers reality as socially and psychologically constructed (Given, 2012) and focuses on qualitative research to capture the opinions, experiences and perspectives of individuals in the construction of knowledge (Hammarberg, Kirkman & De Lacey, 2016). The need to understand the underlying "why's" related to phenomena in a more naturalistic, contextual and holistic way is now widely acknowledged (Smith, 2003) and consequently qualitive research within the disciplines of sports and exercise sciences, including sports nutrition, has significantly increased (Gratton & Jones, 2004). However, there is no single way for a researcher to conduct qualitative research (Denzin & Lincoln, 2008). Instead, qualitative research is an "umbrella term" that encompasses a wide range of research approaches (Greckhamer & Cilesiz, 2022). Identifying the most appropriate qualitative approaches can be led by the nature of the research, underpinning research question itself and the resulting required data, as well as taking into consideration the preferences of the researcher.

Mixed methods is a research approach whereby the researcher collects and analyses both quantitative and qualitative data withing the same study (Creswell & Clark, 2011; Bowers *et al.,* 2013). This approach draws on the potential strengths of both quantitative and qualitative methods to allow the researcher to explore diverse perspectives and uncover relationships that exist between the complex layers of multifaceted research questions (Greene, Caracelli & Graham, 1989). The purposeful mixing of methods in data collection, data analysis and interpretation of the evidence facilitates a more panoramic view of the research landscape as phenomena are viewed through a diverse research lenses (Shorten & Smith, 2017). However, this mixing of methods, often referred to as the "third paradigm", adopts a pragmatic approach to the research (Denscombe, 2008). Pragmatism avoids the controversial issues of truth and reality, and instead acknowledges that there are singular and multiple realities that are open to empirical inquiry when solving practical problems in the "real world" (Feilzer, 2010). Conducting research through a pragmatic paradigm allows the researcher to be flexible and choose the most appropriate approaches to answer the specified research question.

Given the nature of this thesis, pragmatism appears to be the appropriate paradigm to conduct the research within. By taking this approach the most suitable methods will be used at different periods throughout this thesis to best address the research questions and fulfil the objectives of the research. Study 1 utilises a mixed methods approach to quantitatively explore the use of digital platforms by sports nutritionists as part of their current service provision to athletes, whilst also capturing via qualitative methods their experiences and opinions of these digital platforms used in applied practice. Study 2 will draw on qualitative methods to directly engage with athletes to explore their own experiences of communication strategies in applied sports nutrition, as well as capture their thoughts and suggestions for future mobile app supportive solutions. Gathering data from both sports nutritionists and athletes will facilitate a more in-depth understanding of the problems and opportunities that exist within the field of sports nutrition. This diversity of perspectives can also support, and be the catalyst for, innovation (Hofstra *et al.,* 2020). Study 3 will revert back to the use of mixed methods as it seeks to collaboratively design and then pilot a personalised sports nutrition mobile app DBCI.

2.11 Innovation Research

Innovation can be defined as the introduction of something new, an idea or behaviour in the form of a technology, product, service, structure, system or process (French & Torres-Ronda, 2021). However, no academic fields exist exclusively for the study of innovation and defining exactly what innovation research is can be challenging. It has been referred to as a process (Ashby, 2003), a framework (Lichtenthaler, 2011), a paradigm (Meissner & Kotsemir, 2016), and a methodology (Fields, 2015). For the purpose of this thesis, innovation research will be referred to as a methodology, a strategy for conducting the research under a pragmatic paradigm (**Figure 7**). The progressive change demonstrated using this methodology is widespread across many fields including education (Garcia, 2023) and healthcare (Omachonu & Einspruch, 2010), as well as economics (Mansfield, 1968) and sociology (Steil, Victor & Nelson, 2002). In the context of sports and exercise sciences, the main body of innovation research has been published since 2005 (Tjønndal, 2017), hence as an academic field it is still developing. However, within this short timeframe it has contributed to the introduction of clap skates in speed skating, bench skirts in powerlifting (Balmer, Pleasence & Nevill, 2011) and wearable sensors in martial arts (Chi, 2005).

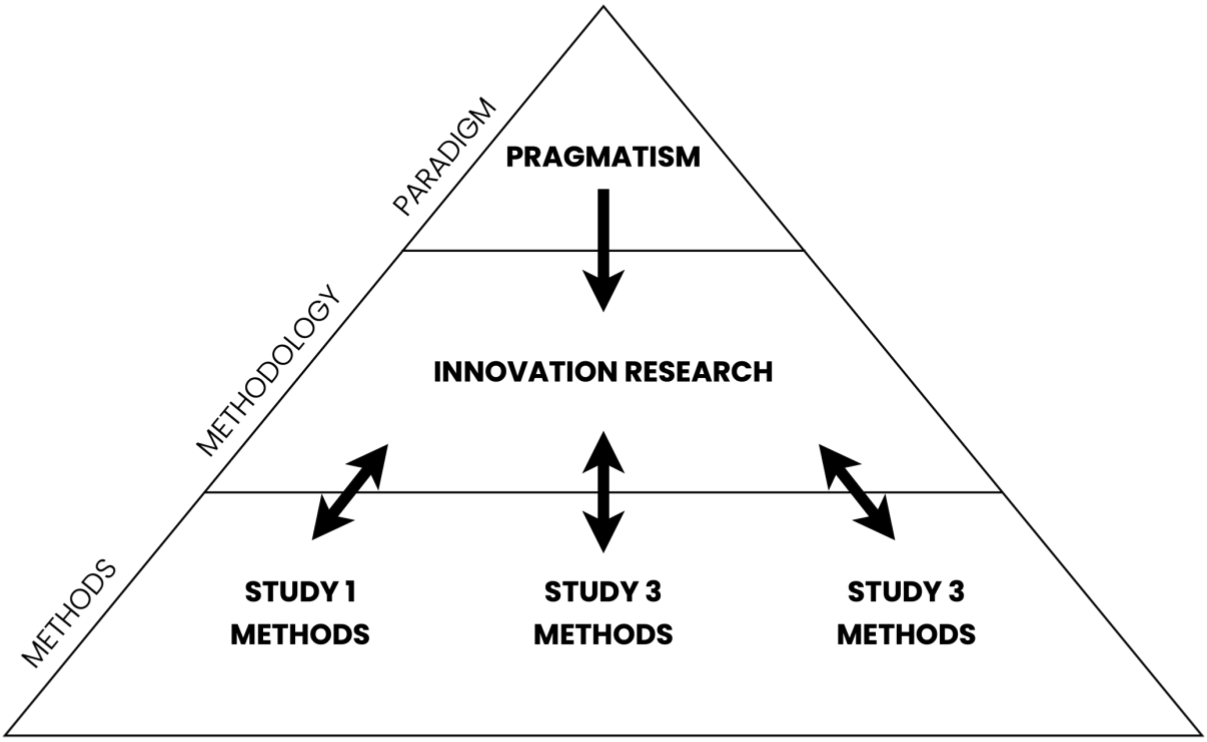


Figure 7. Research framework of thesis.

There is a variety of innovation research models that exist which a project or body of work could be grounded in. Despite this, all models fundamentally adhere to innovation research's typical characteristics of being curiosity led and open ended in nature (Bogers, Chesbrough & Moedas, 2018). Additionally, it has a target, which can include a technology, product, service, structure, system or process (Smith, 2003), as well as requires an element of novelty, which can be facilitated by the combining of disciplines and divergent thinking (Dahm *et al.*, 2021). At its core, innovation research is a creative methodology that follows a series of stages to generate a new innovation. The body of work within this thesis adapts an existing model of innovation research within sports and exercise science (French & Torres-Ronda, 2021) and combines it with a more general conceptual model of innovation, idea generation and related concepts (Smith 2003) to add greater depth to the stages involved (**Figure 8**). Stage one is centred around awareness and recognising a need and identifying a gap in existing knowledge or current performance. This stage aligns with chapters one and two of this current thesis via an introduction and exploration of the existing literature. During stage two interests are initially explored through research to develop knowledge bases. This element of stage two aligns with chapters three (Study 1) via mixed methods research with sports nutritionists and chapter four (Study 2) via qualitative research with athletes. Utilising this newly developed knowledge base, the remainder of stage two focuses on problem solving, invention and design activities to identify suitable innovations. These processes draw on creativity to identify suitable innovations and are explored in chapter five (Study 3, steps one to four) using a Behavioural Design Thinking approach. Stage three focuses on a trial period to investigate the innovation in order to be able to answer several performance and practicality related questions. This is also explored in chapter five (Study 3, step five) which focuses specifically on a pilot test. To conclude, stage four proposes the innovation for adoption, providing justifications for decisions. This element is discussed in chapter six via the general discussion of findings within this thesis.

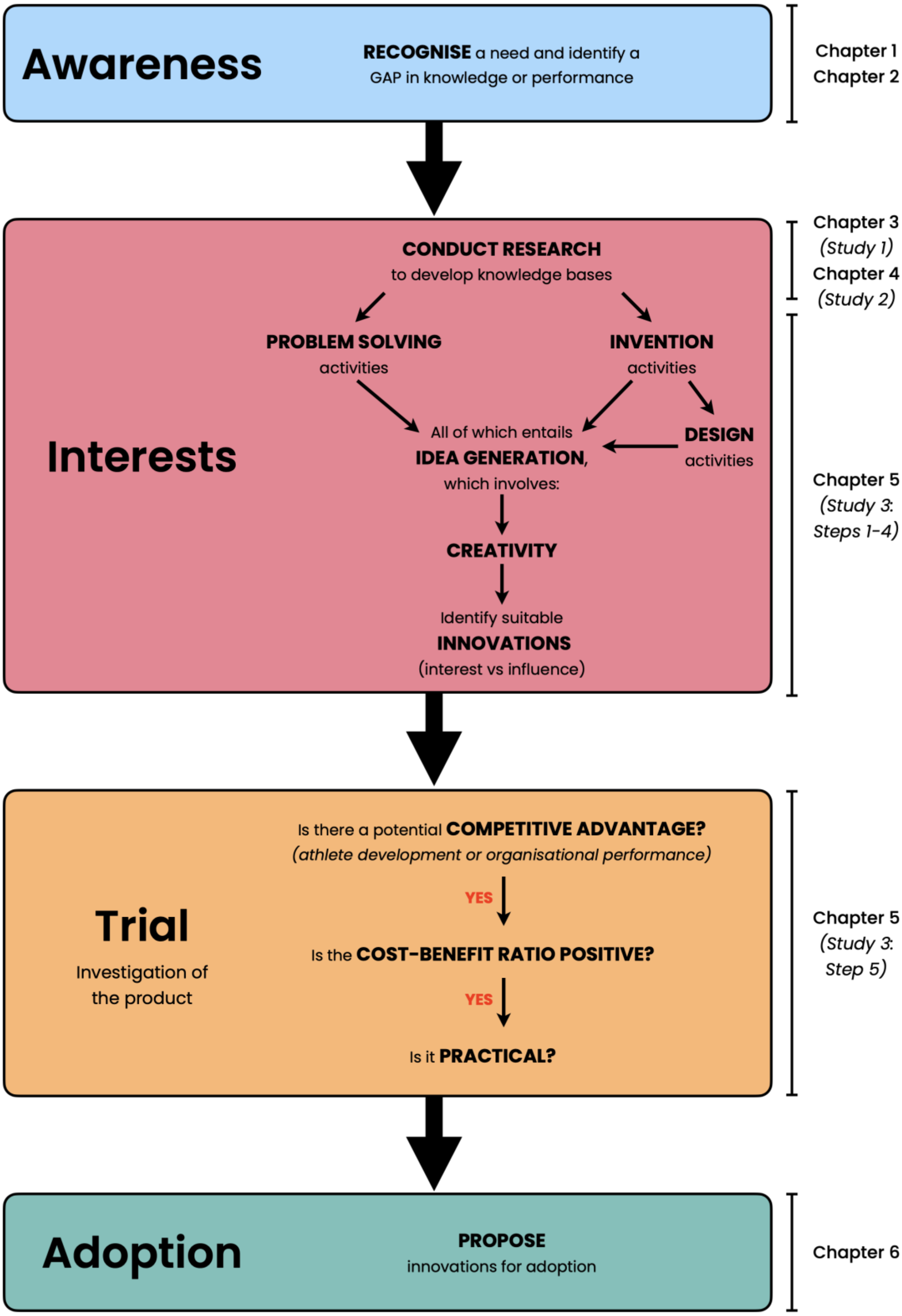


Figure 8. Innovation Research Model (adapted from French & Torres-Ronda, 2021 and Smith, 2003).

2.12 Reflections on the Research Journey: Biographical Position

The art of reflective practice and the resulting documentation of a practitioners' personal growth journey, as well as that of their role as a practitioner, an academic, or in some instances both, has become increasingly popular and gained credibility in recent times (Morton, 2009; Littewood, Morton & Drust, 2014; Martin, 2017). To conclude each of the remaining chapters of this thesis the narrative will briefly transition to a first-person narrative and provide the reader (you) with an account of the researcher's (me) philosophical and biographical location at that time. This opening account introduces my position right at the beginning of the research process.

Coming into this role as a PhD researcher I was deeply aware that my professional strengths lied in applied practice, not research. In fact, prior to commencing this PhD I never previously considered going into academia. My passion was people and the tools I had in my toolbox were listening, conversing, empathising and observing. However, as a sports nutrition practitioner working across multiple sporting organisations at the time, what I was starting to hear, the conversations I was starting to have, and the observations I was making were all shifting, and my curiosity followed. Digital technology was now everywhere and the athletes I was working to support were active daily users themselves. As a result, I started to experiment with its inclusion in my own applied practice following a recommendation from a peer, like many other practitioners at the time. At the beginning, which was about 2014, I started on Facebook (now Meta) by creating "private groups" where I would share nutrition content and have online conversations with athletes. Engagement with this arm of my service provision, which I could deliver from anywhere in the world, flourished and positive athlete feedback was pouring in. However, over time I noticed that I was continually having to pivot platforms and change content as trends moved and it became harder to know what to do. It felt like I was "winging it". This brought some level of excitement given the nature of continual experimentation and my innate curiosity, but it also brought personal frustration at the inconsistency of results and consequent inefficiencies in my efforts. At this time, now spring 2015, the digital landscape was evolving, and my curiosity had reached a tipping point. My reading started to reflect my interests, albeit I had to draw on the literature bases from other fields of practice, and it quickly became apparent that the use digital technology was a novel area within sports nutrition that had many questions yet to be answered, but even more yet to be asked. Following my search for literature, I then started to explore if there were any research opportunities as the topic gave me the energy and passion for academia that I had previously lacked. Unfortunately, when it came to sports nutrition and digital technology there were none. Personally, this was a frustrating experience as it seemed that there may be opportunities to discover new and novel approaches to sports nutrition service provision with digital technology, and that they might have the potential to inform and optimise practice, but no one was asking the question. Following the logic of innovation research methodology, I was now very much experiencing the "awareness" stage as I recognised a need and identified a gap in sports nutrition knowledge and performance with regards the use of digital technology in practice. These combined experiences were what brought me to self-funding this PhD and ultimately formalising an agreement with myself to explore the observations I had made in both my own, as well as my colleagues, applied practice.

Chapter Three:

Study 1: An exploratory study into the use of social media apps by sports nutritionists in applied practice

STUDY MAP

STUDY AND AIMS	OBJECTIVES
STUDY 1 Explore how social media mobile apps are being used by sports nutritionists as part of service provision to athletes, as well as capture their experiences and opinions of its use.	• Determine the prevalence and perception of social media usage by sports nutritionists in practice. • Identify current platform usage, as well as the type, frequency and format of content delivered. • Establish sports nutritionist perspectives on digital training. • Establish sports nutritionists' experiences and opinions of social media use as part of service provision.
STUDY 2 Explore athletes' experiences and opinions of communication strategies in applied sports nutrition, as well as their suggestions for future mobile app supportive solutions.	• Obtain athletes' opinions of contemporary communication strategies in applied sports nutrition. • Establish potential problems and opportunities relevant to the development of a DBCI. • Identify athletes' suggestions for future mobile app supportive solutions.
STUDY 3 Using Behavioural Design Thinking to develop and pilot a personalised sports nutrition digital behaviour change intervention for athletes	• Identify target behaviour and behaviour change requirements for athletes. • Map requirements to theoretical behaviour change model to ground in behaviour change science. • Ideate and design mobile app DBCI features. • Pilot and preliminarily evaluate the personalised sports nutrition mobile app DBCI with athletes.

3.1 Introduction

Social media use is a distinguishing and normative characteristic of recent generations (Brown & Bobkowski, 2011; Cupples & Thomspon, 2010). In the UK, 90% of young adults (aged 16-34 years) are active users of social media (Ofcom, 2015) and 18-25 year olds spend more time engaging with media and technology daily than any other activity (Coyne, Padilla-Walker & Howard, 2013). Social media platforms (e.g. Facebook, Twitter, Instagram, WhatsApp, etc) enable users to create and share content online. This departure from institutionally created content and proliferation of user-generated content has shifted information seeking behaviour in society to the extent that, for some, a refreshed feed from a platform provides an immediate, convenient, and preferred method to keep up to date with news stories and information (Newman *et al.,* 2017).

Given the lack of commercially available industry specific mobile apps for practitioners, as well as the ubiquitous update of social media, sports clinicians have been encouraged to embrace social media and consider its use to deliver digital interventions to their athletes as an extension of their service provision (Ahmed *et al.,* 2015). Online platforms may provide sports nutritionists the opportunity to deliver successful, scalable and cost-effective health, education and behavioural interventions to athlete populations (Héroux *et al.,* 2017; Solbrig *et al.,* 2017). The design and delivery of theoretically driven digital health interventions appears to be effective in improving nutrition knowledge and attitudes, as well as influencing individuals' behaviours (Nour, Chen & Allman-Farinelli, 2016; Pagoto *et al.,* 2013). Social media also provides a network for its users to seek health related social support from people within their network (Oh *et al.,* 2013).

It is clear that online platforms can overcome physical or temporal barriers and provide a cost-effective way to increase interaction, provide social support as well as networks for learning and platforms to share credible information. However, to date there has been limited research to explore how or if sports nutrition practitioners use social media to support their practice with athletes. Identifying the current digital practices of practitioners and their experiences to date is an essential first step towards optimising this digital extension of service provision.

Using a mixed methods approach, this study aimed to explore; how social media is being used by sports nutritionists as part of their service provision to elite athletes. Specifically, to capture: 1) the prevalence and perception of social media use with support athletes; 2) current platform usage, type, frequency and format of content delivered; and 3) perspectives on digital training for sports nutritionists. A secondary aim of this study was to explore practitioners' experiences and opinions of social media use as part of service provision.

3.2 Methods

Overall Study Design

An exploratory sequential mixed methods approach, which integrates the quantitative and qualitative methods during the interpretation phase, similar to Mao (2014), was used during this research. Quantitative data was generated from online surveys and qualitative data was collected from semi-structured interviews with open-ended questions.

Participants

Study entry criteria required that participants had to be registered on the Sports and Exercise Nutrition register (http://www.senr.org.uk/find/) and were working as a sports nutritionist in the UK or Ireland with professional and/or Olympic athletes competing in elite domestic or international competition (e.g. Premier League Football, World Tour Cycling, Olympic Games, etc). Participants were recruited through one of the following mediums: via email directly (retrieved from http://www.senr.org.uk/find/), through the Sports and Exercise Nutrition register (SENr) or through the English Institute of Sport (main science and medicine provider for Olympic sports within the UK). Snowballing sampling was used following initial responses (only practitioners that met the above inclusion criteria were included from snowballing). Participants (*n* = 44) were recruited from a wide range of professional sports organisations (see **Table 2**). The total sample recruited represented 60% of all the practitioners eligible from the chosen sample population that was available based on the above inclusion criteria. Ethical approval was granted by Liverpool John Moores University Research Ethics Committee (ethical approval code 16/SPS/037).

Table 2. Range of sports supported by sports nutritionists (*n* = 44) *.

**The majority of participants reported working across multiple sports, likely reflecting the part-time and consultancy nature of sports nutrition as a profession.*

Sport	Number of Practitioners
American Football	1
Athletics	18
Australian Rules	1
Badminton	1
Basketball	3
Boxing	8
Canoe/Kayaking	3
Cricket	1
Cycling	12
Diving	1
Endurance Running	8
Football	12
Gaelic Football/Hurling	5
Golf	5

Gymnastics	1
Hockey	5
Horse Racing	3
Judo	2
MMA	4
Netball	1
Rowing	6
Rugby League	4
Rugby Union	14
Speed Skating	1
Squash	1
Swimming	8
Taekwondo	5
Tennis	4
Triathlon	11
Weightlifting	4

Procedures

All participants completed an online survey detailing their social media use. The questions included were taken both directly, and adapted from, the Sensis Social Media Report (2016) to describe practitioners' personal use of social media as a consumer as well as their professional usage as a service provider. The Sensis Social Media Report (2016) has been deployed by governments for more than five years as a benchmarking tool designed specifically to understand how individuals and businesses are using social media. The questions adapted from this survey were amended to be more relevant to the business sector of sports nutrition, instead of general businesses, and to provide depth and insight into the use of social media as part of a practitioner's service provision. The questionnaire included the following categories: 1) demographic and background information, 2) personal social media usage, 3) professional social media usage. Practitioners who reported not using social media (n = 5) to support practice were excluded from section three of the online survey. All categories provided practitioners with a mix of open ended and closed multiple-choice questions. Response data was collected and stored online using online survey cloud software (Survey Monkey Inc., CA, USA). The questionnaire was firstly piloted with a small sample (n = 5) of MSc and PhD sports nutrition students, but these results were not included in the final analysis. A total of two multiple choice style questions were removed following this pilot and following feedback to reduce the time taken to complete the online survey.

At the end of the survey all participants were given the opportunity to opt into a follow up interview to discuss views, experiences, beliefs and motivations for use or disuse further (Gill *et al.,* 2008). There was a total of 25 volunteers of which 16 took part in semi-structured interviews. After 16 respondents saturation was achieved and it was not deemed necessary to collect further interview data by the lead researcher. Saturation was determined using a hybrid model of data saturation and inductive thematic saturation whereby new data appeared to consistently repeat what was expressed in previous data, and no additional codes emerged whereby the researcher could develop new higher order themes or subthemes (Saunders *et al.,* 2018). Interview questions sought to add depth and context to the survey questions, specifically to explore practitioners' experiences and opinions of social media use in practice, as well as to establish rationales or factors for use or disuse. Initial questions were followed up with naturally occurring 'probing' questions, which facilitated further depth in responses from participants (Gratton & Jones, 2004; Turner, 2010).

Interviews were either conducted in a face-to-face format at participant place of work (n = 2), or via the telephone (n = 14). All interviews that occurred face to face were recorded using a dictaphone, whereas interviews that occurred over the phone were recorded using the TapeACall app (TapeACall Pro: Call Recorder, Epic Enterprises LLC). Subsequently all interviews were transcribed verbatim. Average interview length was 14 minutes.

Data Analysis

The results of the online survey are reported as descriptive statistics. All interview transcripts were uploaded to the NVivo10 software package (NVivo10 for Mac, QSP Int., Australia) to facilitate the analysis process by managing and organising data. A six-stage process of thematic analysis was adopted (Braun & Clarke, 2006; Clarke & Braun, 2017). Immersion of the data was achieved through multiple readings of the transcripts. Relevant content was identified from each of the transcripts by an initial systematic line-by-line coding process and assessed for reliability by a second coder. Once coding was complete, content was arranged to identify recurring themes that ran through the data, developing identifiable frameworks. At this stage, some individual codes were transferred to other themes. Before writing the report on the outcomes of data analysis, each of the themes was named or defined to clearly give the reader a sense of each one. Member checks with a selection (*n* = 7) of practitioners (selected based upon availability) were used to check the accuracy and trustworthiness of the data (Birt *et al.*, 2016).

3.3 Results

Online Survey

The majority of participants had 3 years or more applied experience working with athletes (23% with 1-2 years' experience, 27% with 3-5 years' experience, 9% with 5-8 years' experience, and 34% with 8+ years' experience). Less than 7% of the participants had 6-12 months applied experience working with athletes. Practitioners worked across various and multiple levels of elite sport (elite international, elite domestic, and academy/development) with 80% (*n* = 35) of practitioners reporting working at elite international level and 64% (*n* = 28) and 55% (*n* = 24) reporting working at elite domestic and academy/development levels respectively.

Social media was used by 89% (*n* = 39) of participants to provide nutrition information to their athletes. A total of 5% of participants had received formal social media training in how to develop social media skills and resources for online interventions, whereas 84% reported this training would be something they would be interested in. Of the participants who used social media (*n* = 39) to support their practice, 97% reported finding it beneficial. The types of information provided and the percentage of these participants providing this can be seen in **Table 3**.

Table 3. Type of nutrition information provided across each social media platform by sports nutritionists (%).

Platform	**Recipes**	**Information/ Facts**	**Nutrition Plans**	**Not used**
WhatsApp *(n)*	**59%** *(23)*	**69%** *(27)*	**44%** *(17)*	**18%** *(7)*
Facebook *(n)*	**41%** *(16)*	**46%** *(18)*	**10%** *(4)*	**38%** *(15)*
Twitter *(n)*	**44%** *(17)*	**79%** *(31)*	**5%** *(2)*	**8%** *(3)*
Instagram *(n)*	**44%** *(17)*	**21%** *(8)*	**5%** *(2)*	**44%** *(17)*
Snapchat *(n)*	**10%** *(4)*	**10%** *(4)*	**0%** *(0)*	**67%** *(26)*
LinkedIn *(n)*	**3%** *(1)*	**10%** *(4)*	**3%** *(1)*	**74%** *(29)*
YouTube *(n)*	**13%** *(5)*	**5%** *(2)*	**3%** *(1)*	**72%** *(28)*
Google+ *(n)*	**5%** *(2)*	**5%** *(2)*	**5%** *(2)*	**80%** *(31)*
Pinterest *(n)*	**5%** *(2)*	**3%** *(1)*	**3%** *(1)*	**79%** *(31)*

Pictures/Infographics were the preferred type of content developed and delivered over social media and was used by 77% of the participants. Text (62%), <30 second videos (29%), and 30-90 second videos (21%) were also used by participants. A total of 31% reported developing and delivering all of the above types of content. Smartphones were the preferred device to engage and interact with social media from, used by 98% of total participants (*n* = 44). Laptops (59%), tablets (30%) and desktops (11%) were also used but to a lesser extent. Social media was used by 71% of participants to keep up to date with research. Social media was also used to find recipes for meals (39%), get athlete training information such as schedules and timings (27%), as well as to research products and foods (23%). All participants reported having multiple social media accounts. Twitter was the only platform that 100% of participants had an account with and over half of the participants also reported having accounts with Facebook (93%), WhatsApp (86%), LinkedIn (86%), Instagram (68%) and Snapchat (52%). All participants were frequent users of social media personally and professionally (see **Table 4**).

Table 4. Top 7 social media platforms used by sports nutritionists (%) and their daily frequency of visits (for personal and professional use).

		Daily Use					
	Platform	**Never Use**	**1 – 2**	**3 – 5**	**6 – 10**	**11 – 19**	**20+**
Most frequently visited	WhatsApp	**7%**	**14%**	**20%**	**11%**	**18%**	**30%**
	(n)	*(3)*	*(6)*	*(9)*	*(5)*	*(8)*	*(13)*
	Facebook	**11%**	**32%**	**25%**	**20%**	**7%**	**5%**
	(n)	*(5)*	*(14)*	*(11)*	*(9)*	*(3)*	*(2)*
	Twitter	**0%**	**41%**	**32%**	**16%**	**9%**	**2%**
	(n)	*(0)*	*(18)*	*(14)*	*(7)*	*(4)*	*(1)*
	Instagram	**34%**	**32%**	**14%**	**18%**	**0%**	**2%**
	(n)	*(15)*	*(14)*	*(6)*	*(8)*	*(0)*	*(1)*

Snapchat	**55%**	**32%**	**9%**	**0%**	**2%**	**2%**
(n)	*(24)*	*(14)*	*(4)*	*(0)*	*(1)*	*(1)*
LinkedIn	**39%**	**57%**	**2%**	**0%**	**2%**	**0%**
(n)	*(17)*	*(25)*	*(1)*	*(0)*	*(1)*	*(0)*
YouTube	**52%**	**43%**	**2%**	**0%**	**0%**	**0%**
(n)	*(23)*	*(19)*	*(1)*	*(0)*	*(0)*	*(0)*
Least frequently visited						

Interviews

Five higher order themes and five sub themes emerged from the data synthesis process. These have been clustered into two general dimensions, which are (1) Enablers and (2) Challenges to usage in practice. The dimension entitled enablers gives insight into how and why social media is being used by participants to support their practice. The dimension entitled challenges highlights experiences, opinions and practical issues that participants currently have with social media. Evidence is provided in the form of indicative verbatim quotations to highlight the participants' narrative, with reference made to the number of participants that contributed to each theme.

Enablers

This initial dimension demonstrates how and why using social media may be helping sports nutritionists to support their service provision with elite athletes. Three themes, *communication* *medium change*, *mobile learning* and *visual learning*, embodied this general dimension identified in **Table 5**.

Table 5. Enablers to support the use of social media apps by sports nutritionists in applied practice.

Raw Data	**Higher Order Theme**	**General Dimension**
"I can e-mail an athlete and they never even look at it, WhatsApp and they'll reply within minutes, it's ridiculous. I think it's just an age thing, like, if you're a certain age. Even phone calls, like they don't even call you anymore" (Practitioner 6)	Communication Medium Change (n=15)	Enablers
"WhatsApp is very, very useful and very efficient at information sharing, mainly because it is readily available on people's phones and you know, you can normally get a pretty instantaneous response to questions or you can, in real time, discuss nutrition" (Practitioner 9)	Mobile Learning (n=9)	
"Everyone has their phone in their hands now and I genuinely think people don't really want to read, they want to see and interpret the visuals" (Practitioner 8)	Visual Learning (n=6)	

Practitioners described scenarios in which social media has benefited how they communicate with their athletes:

"You go to a camp or a competition and WhatsApp, and group messages are invaluable, a very quick way to update people, very useful" (Practitioner 3).

The use of nudges to facilitate mobile learning was highlighted:

"We use social media as just a prompting exercise as opposed to actually pure education" (Practitioner 4).

The transition away from traditional e-mail was highlighted by a number of practitioners:

"They seem to get more out of that (WhatsApp) than if I sent them an e-mail. I'm not sure how many people open their e-mails" (Practitioner 11).

Also highlighted was the athletes' preference for material:

"I did a survey of all the athletes just a few weeks ago actually and they all said that they preferred the videos than having to actually read material" (Practitioner 13).

Challeneges

Table 6 illustrates the seven higher order themes that express the dimension of challenges to social media usage in practice described by sports nutritionists.

Table 6. Challenges to the use of social media apps by sports nutritionists in applied practice.

Raw Data	**Sub Theme**	**Higher Order Theme**	**General Dimension**
"I think it would be good to understand, formally, from the athletes, actually what, like, how often do they check it, the best times and all that kind of stuff." (Practitioner 6)	*Optimising Digital Intervention Effectiveness (n = 13)*	Lack of Digital Intervention Training (*n* = 13)	Challenges
"I definitely think it has some impact but I can't say how much…how do you measure it?" (Practitioner 11)	*Measuring Impact (n = 5)*		
"The age group that I'm working with at the moment is probably averages about 17 and 25 or so and I think a lot of them just don't use e-mail anymore as their primary method of communication and they certainly don't understand that business still revolves around e-mail and that's one of my challenges" (Practitioner 3)	*Generational Differences (n = 4)*		
"In our domain I think training wise, the training that you'd need in our domain would be more around safety and confidentiality" (Practitioner 2)	*Privacy and Confidentiality (n = 5)*		
"I think we could get a lot better behaviour change by using these platforms and visual learning tools…I think that's definitely a way nutrition is going over the next few years." (Practitioner 15)	*Developing Behaviour Change Interventions (n = 4)*		
"In terms of content it could take him a full day" (Practitioner 13)		Time Requirement (*n* = 4)	

The majority of practitioners highlighted a lack of digital intervention training as a barrier to social media usage:

> *"I think the kind of areas of behaviour change, as a whole, in terms of nutrition is a bit under looked at times and probably one of the biggest areas to influence behaviour in getting the message right"* (Practitioner 15).

> *"If our whole point is to make an impact and influence athletes' food choices, then why don't we use the most effective ways of doing that and I think if we could have more training on how best to use social media then that would be good"* (Practitioner 1).

> *"I can recognise that I need to improve a lot on it and I guess I just kind of haven't had the time at the minute. It's not one of my main priorities at the minute. If someone were to put it in front of me and say, 'this training course is on' then I would definitely go"* (Practitioner 13).

It is important to note however, that despite the majority viewing digital interventions as beneficial, there was some disparity in the field as some practitioners gave their reasons for choosing to not use social media:

> *"I can see the logic but I kind of feel that if you have to nudge someone to do that then you probably haven't done the job right in the first place"* (Practitioner 13).

3.4 Discussion

The primary aim of this study was to explore how sports nutritionists are using social media as part of their service provision to elite athletes. The secondary aim was to explore practitioners' experiences and opinions of social media use as part of service provision. Using mixed methods, our data highlights the prevalence and perceived benefits of social media use by sports nutritionists as part of their service provision. Twitter, Facebook and WhatsApp were reported as the most popular platforms amongst practitioners. The underlying trends for social media use were to facilitate mobile and visual learning, as well as educate, nudge, and communicate with athletes across various environments, contexts and times of day. However, our data demonstrates that sports nutritionists' lack digital intervention training, echoed by their current inability in how to measure digital intervention impact, as well as their requests to better understand behaviour change interventions. Furthermore, our data highlights that sports nutritionists now want formalised training pathways to optimise their digital service provision.

Communication Change

The survey data highlights that sports nutritionists are not exempt from global trends as practitioners adopt similar practices to other service provision industries (We Are Social, 2017). Qualitative findings suggest a shift from traditional communication support practices of phone calls and follow up emails to platforms such as WhatsApp. These findings are in agreement with recent global communication discoveries by Deloitte (2016), who demonstrated that 31% of smartphones users no longer make traditional voice calls in a given week. Furthermore, Montag *et al.,* (2016) found that WhatsApp now accounts for an average of 20% of an individual's phone usage, with users averaging approximately 32 minutes a day on the platform. It appears that nutritionists have now, potentially inadvertently, established a “messaging support service” between themselves and the athletes they work with.

Practitioners’ own frequency of visits to social media sites also provides insight into how we interact and consume information. For example, 30% of practitioners report visiting WhatsApp more than 20 times a day, therefore it is likely that most of these interactions are shorter in nature than traditional email. A similar conclusion was reached by Andrews *et al.*, (2015) who reported that UK university students and staff are using their phones on average 85 times a day, with 55% of all uses less than 30 seconds in duration, likely to reflect the time taken to read or respond to a short message, voice note or to check notifications. The implications of these findings bring to light new considerations for the modern sports nutritionist. The movement towards smaller, bit-sized chunks of communication and content, and away from phone calls and emails now challenges practitioner’s digital delivery to not only be clear and concise, but also innovative in how they deliver messages to effectively engage and influence the athlete in the short period of time available.

Mobile Learning, Nudging, and Visual Learning

Our findings suggest that sports nutritionists are incorporating an anytime and anywhere mobile learning approach as they communicate “in real time” (e.g. Practitioner 9) to educate, collaborate and communicate with athletes across various environments, contexts and times of day. This finding is consistent with trends in pedagogy, again highlighting sports nutrition is no different to global trends, as social media and online platforms continue to establish a supporting role for itself in the education system (Moran, Seaman & Tinti-Kane, 2011; Cheston, Flickinger & Chisolm, 2013; Brooks, 2016; Biloš, Turkalj & Kelić, 2017). Pascarella and Terenzini (2005) investigated the impacts of incorporating these platforms into the teaching activities of their university faculties and found that the most effective faculty members used social media with their students as a platform for active learning, as well as to engage students in real-time with minimal hindrances. Maloney, Moss and Ilic (2014) explored students' perspectives of these platforms use in education, demonstrating that students felt it was appropriate and would benefit their learning by facilitating peer collaboration, enhanced communication and complementary learning. It has been stated that this augmentation of practice through mobile devices and applications can enrich traditional learning (Biloš *et al.*, 2017). Perhaps this is because mobile learning facilitates communication in a highly situated and contextualised manner, enabling learning to take place in the context in which it is applied, as proposed by the Situated Learning Theory (Lave & Wenger, 1991). However, it appeared that not all practitioners used these online platforms to educate and communicate. Practitioners also used social media as a "prompting exercise" (e.g. Practitioner 4). This is more commonly referred to as "nudging", a concept popularised by the work for Thaler and Sustein (2009). By delivering these "nudges" practitioners are inadvertently adopting the role of a choice architect as they attempt to use the digital environment to influence real world decisions and behaviours in athletes. It appears there is an opportunity now for practitioners to refine and potentially systemise these nudges to optimise their effectiveness at influencing behaviour (Abdukadirov, 2016).

Both the survey and interview results highlight that practitioners are making attempts to be more innovative by incorporating mobile learning and visual learning techniques together. This example approach has been shown to be effective in other fields, for example, Krum (2013) reported individuals to be 6.5 times more likely to remember new information if they had learnt it from an infographic rather than text alone. Similarly, Delp and Jones (1996) explored the effect of pictures on patient comprehension and compliance and found that the use of pictures and text increased patients' comprehension of the instructions by 40% and compliance by 23% rather than text alone. They also found that the inclusion of pictures with text improved compliance by 37% over text alone in participants without a high school education. These findings highlight the value of sports nutritionists investing in digital resource development, especially if they are working with youth athletes. However, before spending more time developing and delivering content online it seems important practitioners take a step back and consider how to optimise their digital intervention effectiveness, as well as clearly identify how to quantify the impact of their digital interventions instead of relying on their perceptions.

Training

The overwhelming majority of practitioners using social media reported in the survey that it was beneficial to their service provision despite a lack of industry training, suggesting that these tools are easy to use and the skills required can be learned autonomously. The survey did however identify that practitioners would be interested in formal digital training, whereas the interviews detailed areas of training, such as behaviour change and digital safety regulations that sports nutritionists would like to receive to optimise this digital element of service provision. Presently, sports nutrition appears to exist in a sport science echo chamber, siloed from other fields, such as behaviour change, mHealth and design, who are most likely the parties needed to collaborate with to optimise online service provision and digital intervention delivery. It is possible that this may be because sports nutritionists are predominantly trained in the physiological aspects of sport and exercise science, with limited consideration given to the behaviour change, technology and design aspects of the discipline which may provide solutions for the majority of challenges highlighted by sports nutritionists in this study.

3.5 Conclusion

Our data highlights the prevalence and perceived benefits of social media use by sports nutritionists as part of their service provision. A total of 89% of the participants used social media as part of their practice. WhatsApp was the most frequently visited platform whereas Twitter, WhatsApp and Facebook were the most popular for providing information and resources. The main trends for social media use were to facilitate mobile and visual learning, as well as educate, nudge, and communicate with athletes across various environments, contexts and times of day. We also highlight the clear challenges practitioners are facing, such as lack of training, as they embrace social media and discuss some of the available solutions to progress this digital extension of practice. Despite these platforms introducing new legal, ethical and professional considerations for sports nutritionists, they do provide networks for scalable interventions and platforms to share credible information. Professional education now could support sports nutritionists to overcome the training and time challenges highlighted and develop digital professionalism. Additionally, the uptake of mobile apps as an extension of sports nutritionists' service provision highlights the opportunity for the development of an industry specific digital platform that can better cater to needs of the practitioner. New, and ever iterating tools, mean new competencies, collaborations and knowledge are required if these external forces are to be harnessed to optimise practice.

3.6 Reflections on the Research Journey: Evolving Landscape

I am (finally) up and running! Up until this point I felt very much like a practitioner who only talked about research and had a general awareness of a technology trend in the discipline, but this was only based on observations. After completing Study 1 everything became a bit more "real" as new contributions to the knowledge base had begun and I managed to transition to a dual practitioner-researcher identity.

During the first study of this present thesis, I learned how a wide variety of other sports nutritionists felt and thought about using digital means such as social media platforms as an extension of service provision, as well as what they said about and did with the technology. I honestly became fascinated by how and why other practitioners operated the way they did. After analysing the survey data, it was apparent that using social media usage in practice was popular amongst my practitioner peers. However, what I found particularly interesting was the interviews, as they uncovered that the inclusion of these technologies was really a bottom-up movement. At no point had it ever formally been decided that these digital tools would be used as an extension of practice in applied sports nutrition, it just happened. What originated in general society had spilled over into our profession with: mass uptake; no formal training by many (although not all); no clear method to capture effectiveness; and to top it off very few sports nutritionists even questioning the process. This was a major wake up call for me early in my research journey. What it highlighted to me was that sports nutrition is not exempt from societal trends. Additionally, the potential impact of peer norms highlighted the hypothetical risk of an echo-chamber and groupthink within the discipline. To mitigate this risk and ensure this PhD thesis would deliver novelty I decided at this moment (late 2016, early 2017) to significantly broaden my horizons beyond not just the sports nutrition literature, but beyond the evidence bases that exists across the range of sports science disciplines.

At the same time the global technology landscape was evolving rapidly. New social media features (e.g. Reels) and platforms (e.g. TikTok) were being developed and other types of mobile apps which could compliment wearable devices (e.g. Whoop) were emerging while I was analysing the data in Study 1 and preparing it for publication. Initially I felt frustrated by this and wished I could do Study 1 all over again to capture additional insights into the new platforms and apps. However, what I quickly realised was that the pace of change in technology globally was simply too fast and that for the purpose of this PhD I would need to remain agnostic to platforms and features. Instead, my focus needed to remain on the creation of new knowledge that could be used to facilitate innovation at a later timepoint because right now it was not possible to tell what would and wouldn't be done in the years to follow. Upon reflection I realise Study 1 enabled me to do more than just answer the original research questions of the study, it also helped me think more critically about my own general research journey and prompted me to explore further into the readings and practices other fields and industries such as behaviour change, product development, design and software engineering.

Chapter Four:

Study 2: Athlete experiences of communication strategies in applied sports nutrition and future considerations for mobile app supportive solutions

STUDY MAP

STUDY AND AIMS	OBJECTIVES	OUTCOMES
STUDY 1 Explore how social media mobile apps are being used by sports nutritionists as part of service provision to athletes, as well as capture their experiences and opinions of its use.	• Determine the prevalence and perception of social media usage by sports nutritionists in practice. • Identify current platform usage, as well as the type, frequency and format of content delivered. • Establish sports nutritionist perspectives on digital training. • Establish sports nutritionists' experiences and opinions of social media use as part of service provision.	• Widespread use of social media and perceived as beneficial. • Multiple platforms used for varied content delivery. • A lack of and desire for training for digital interventions. • Embraced as an extension of service provision.
STUDY 2 Explore athletes' experiences and opinions of communication strategies in applied sports nutrition, as well as their suggestions for future mobile app supportive solutions.	• Obtain athletes' opinions of contemporary communication strategies in applied sports nutrition. • Establish potential problems and opportunities relevant to the development of a DBCI. • Identify athletes' suggestions for future mobile app supportive solutions.	
STUDY 3 Using Behavioural Design Thinking to develop and pilot a personalised sports nutrition digital behaviour change intervention for athletes	• Identify target behaviour and behaviour change requirements for athletes. • Map requirements to theoretical behaviour change model to ground in behaviour change science. • Ideate and design mobile app DBCI features. • Pilot and preliminarily evaluate the personalised sports nutrition mobile app DBCI with athletes.	

4.1 Introduction

The daily nutritional practices of an athlete can influence not only how their body adapts to a training stimulus and performs in competition, but also how their body maintains immune function and supports general health (Close *et al.*, 2016; Impey *et al.*, 2018; Walsh, 2019). Dietary strategies have been developed during the last 50 years to optimise the type, timing and total amounts of foods, fluids and ergogenic aids that an athlete may consume (Thomas, Erdman & Burke, 2016). More recently, between 2002 and 2022, sports nutrition has experienced a 17-fold increase in the number of research papers published making it one of the fastest growing and evolving disciplines in sports and exercise science (see **1.1**). This rapid rise in research is reflected in the applied setting where it is now common practice for sports teams, organisations and institutes to employ sports nutritionists on a part-time, full-time or consultancy basis, as highlighted by Study 1.

The growing popularity of applied sports nutrition has also coincided with the emergence and uptake of Web 2.0's novel digital technologies (McGee & Begg, 2008). On a global scale, these social platforms, such as Facebook, WhatsApp, Instagram, YouTube and Twitter, have changed how we communicate, as well as how we generate, access and consume content (Gagnon & Sabus, 2014). Practitioners have been encouraged to embrace these tools and consider their use for intervention delivery and service provision in applied settings (Ahmed *et al.*, 2015). Study 1 demonstrated a widespread uptake of these digital communication tools in applied sports nutrition practice where their implementation has been deemed beneficial by sports nutrition practitioners.

Despite the rapid uptake of novel digital technologies by practitioners, and increased publication of sports nutrition research over the past decade, there remains a distinct absence of implementation science research exploring the application of such tools in the sports nutrition literature. Instead, position stands and practical recommendations remain focused on increasing our understanding of nutrition's impact on metabolism, physiology and physical performance, resulting in improvements in knowledge (Close *et al.,* 2016; Thomas, Erdman & Burke, 2016; Stellingwerff *et al.,* 2019a; Collins *et al.,* 2020). This lack of implementation research in the sports nutrition field may now be impeding the application of the progress made in the laboratory (Eccles & Mittman, 2006; Bentley *et al.*, 2020). Instead, as discussed in **2.3**, applied intervention studies remain focused on education despite an awareness that the translation of knowledge into nutrition behaviours in athletes remains imperfect (Heaney *et al.,* 2011; Bentley *et al.,* 2021; Foo *et al.,* 2021; Tam *et al.,* 2021).

As sports nutrition research continues to develop and the use of technology continues to permeate practice, service provision may now benefit from increasing its understanding of how athletes experience the communication strategies employed by a practitioner in applied sports nutrition. These reported experiences may help sports nutritionists identify areas for improvement in practice; determine any current or potential future problems; enable practitioners to better target the use of their time when providing support to athletes, organisations and institutions; and may support the development of innovative ideas for delivery (Crawford, 2002).

Using qualitative methods, this study aimed to explore athletes' experiences and opinions of communication strategies in applied sports nutrition, as well as their suggestions for future mobile app supportive solutions. This acquired understanding of how athletes experience and think about the support they receive, as well as their suggestions for technology, will contribute to development of new and improved applied service provision strategies.

4.2 Methods

Overall Study Design

A qualitative approach, similar to Bentley and colleagues (2021), was used during this study. Qualitative data was generated from semi-structured focus groups with open ended questions.

Participants

A purposive sampling approach was used to identify athletes from high performance sport that met the following inclusion criteria: (a) >16 years of age, and (b) were classified as tier 3 or above according to the 6-tiered Participant Classification Framework (McKay *et al.*, 2022). The Participation Classification Framework uses training volume and performance metrics to classify participants to one of the following: Tier 0: Sedentary; Tier 1: Recreationally Active; Tier 2: Trained/Developmental; Tier 3: Highly Trained/National Level; Tier 4: Elite/International Level; or Tier 5: World Class. An initial e-mail describing the study was distributed to a variety of sport science and medicine practitioners working in UK high performance sport. Practitioners volunteered as gatekeepers at their sporting organisations, inviting athletes to participate and helping arrange focus group dates and times for the interested parties. Nine groups of athletes (n = 41; male = 24, female = 17; mean = 6; range = 3 to 8) from five sports (football n = 21, rugby union n = 8, athletics n = 3, cycling n = 4, and boxing n = 5) were recruited to participate in this qualitative study. Of the intermittent field sports (football and rugby union), 52% of athletes were classified as tier 3, 27% were classified as tier 4, and the remaining 21% of athletes were classified as tier 5. In the remaining sports (athletics, cycling and boxing), 83% of athletes were classified as tier 4, with the remaining 17% of athletes classified as tier 5. All participants were full time professional athletes with an average age of 24 years (SD = 4.59). The current level of nutrition service provision received by the participants varied from 2 days per month consultancy up to full time support. All participants reported receiving a minimum of 2 years and a maximum of 15 years of nutrition service provision as part of their sporting careers to date (average 6.6 years, SD = 4.11).

Procedures

This qualitative study used focus groups, designed and reported in line with the Consolidated Criteria for Reporting Qualitative Research (COREQ) (Tong *et al.*, 2007). Focus group interview guides were developed by the lead researcher (DD) and a member of the research team to explore participants experiences and opinions of communication strategies in applied sports nutrition, as well as their suggestions for future digital technology supportive solutions. The questions devised were open ended and supported by a range of additional prompts to probe for further explanation. Semi-structured interviewing techniques allowed for in-depth exploration of the topics in a flexible but consistent manner (Sparkes & Smith, 2014). This approach ensured participants had the opportunity to share their own thoughts and feelings toward to the topics. The interview questions were piloted with a small sample (n = 4) of tier 3 and tier 4 athletes prior to data collection. One question was removed following this pilot and athlete feedback to avoid repetition. No data generated from the pilot was included in the final analysis.

All focus groups were facilitated by one moderator (DD), who was trained in qualitative research methods. The composition of these focus groups was largely dictated to by athlete availability around their training and competition schedules. However, efforts were made with the gatekeeper to select participants of different ages to encourage different points of view, as well participants with different degrees of experience with nutrition support to avoid groupthink. To generate rich interactions the moderator played an active role in facilitating the group discussions and efforts to establish good rapport were made with the participants throughout (Tausch & Menold, 2016). Each focus group was individually adapted to the flow of discussion taking place. Planned as well as naturally occurring "probing" questions were used to add further depth, context and insight to the responses from participants (Gratton & Jones, 2004; Turner, 2010; Sparkes & Smith, 2014). To operationalise, the moderator directed follow up questions and probes in response to other participants initial answers to specific individuals at various timepoints to ensure there was a variety of participants experiences and opinions captured during this process. Focus groups were deemed suitable for this exploratory research due to the spontaneous, expressive and emotional interaction they can generate as participants are able to respond to and build upon one another's comments, stimulating a breadth of discussion (Wong, 2008; Sparkes & Smith, 2014). Additionally, focus groups can challenge and develop an individual's viewpoint and provides the opportunity for norms and assumptions to be revealed (Kitzinger, 1995). Focus groups were carried out face to face to promote participation and took place across a range of UK based training centres (Tausch & Menold, 2016). Written consent was obtained from participants prior to each focus group commencing. Focus groups lasted an average of 27 minutes (SD = 7) and were recorded using a handheld audio recording device (Tascam DR-05X). Field notes and a research journal were kept during data collection.

Data Analysis

Given that the researcher's role is vital in knowledge production, a reflexive thematic analysis (TA) approach was implemented (Braun & Clarke, 2019). Reflexive TA facilitated a richer and more nuanced reading of the data as it required the researchers to continually question and query any assumptions made during the interpretation and coding of the data (Braun & Clarke, 2019). To identify and construct patterns of meaning from the data, the analysis followed a six-stage approach (Braun & Clarke, 2006). Initially the audio recordings were listened to multiple times before being transcribed verbatim. Familiarisation with the data (Stage 1) continued as transcripts were repeatedly read and initial notes for coding were made. Following familiarisation, initial codes were generated inductively (Stage 2) using NVivo 11 software. Stage 3 involved organising codes into the following four semantic themes: (1) communication strategies and information delivery, (2) acceptance and adoption of the online practitioner, (3) a personalisation problem and (4) preferred mobile app features. Themes were then reviewed by the research team (Stage 4) to check and challenge any assumptions made by DD during the interpretation of the data. A thematic map was used to reflect the meanings evident in the data set as a whole. Themes were then defined and refined (Stage 5) to ensure they individually captured the essence of what each theme was about. As a result, theme 4 was renamed "tailoring technology" and new sub themes developed: (4a) periodised and personalised nutrition planning, (4b) feedback loops, (4c) nudges, and (4d) performance focused content. For the final stage (Stage 6), an analytic narrative was produced and is presented in this manuscript. Throughout, pseudonyms were assigned to participants to protect their identity. Member reflections were carried out with a selection (n = 9) of participants (selected based upon availability) to generate additional data and insights, as well as to explore any gaps in the results and concerns the participants had over the interpretations of the findings (Braun & Clarke, 2013; Smith & McGannon, 2017).

4.3 Results

The purpose of this study was to explore athletes' experiences and opinions of present-day communication strategies in elite sports nutrition, as well as their suggestions for future mobile app supportive solutions. The focus group analysis identified a total of four higher order themes and five sub themes. A detailed description of each theme and associated sub theme is outlined in this section with evidence in the form of indicative verbatim quotations to highlight the participants narrative. A summary of these findings is presented in **Table 7**. Athletes experienced a hybrid human-computer approach to sports nutrition support, whereby practitioners employed a range of in-person and remote digital methods, to communicate with and deliver information to athletes. Athletes appeared unsatisfied with the current nutrition support they received. Lack of personalisation and limited contact time with practitioners were highlighted as contributing to this feeling of discontentment. Despite perceptions of limited contact time, athletes acknowledged the usefulness of receiving remote nutrition support, and reported a general acceptance and adoption of this online service. Regarding mobile app supportive solutions, athletes identified an opportunity for the introduction of tailoring technology to help them periodise and plan their nutrition in line with the demands of their activity. Supportive features to help drive engagement and self-monitoring were also suggested by athletes as being useful.

Table 7. A summary table of identified themes following athlete focus group analysis.

Raw Data	Sub Theme	Higher Order Theme
"The nutritionist is here most of the time, but I probably only really speak to them seriously about nutrition maybe once every 3 weeks. That would be about right. I think it's got better this year. I think last year you could not have really had a proper conversation for a couple of months at a time" (Athlete 1, Focus Group 2)		Communication strategies & information delivery *(n = 33)*
"having WhatsApp conversations are handy because you can literally send a picture or have a chat about a recipe or something quite quickly" (Athlete 1, Focus Group 8)		Acceptance and adoption of the online practitioner *(n = 26)*
"I think what the nutritionist does is pretty much pointless I'd say. It should	*Lack of personalisation (n = 32)*	A personalisation problem *(n = 47)*

be related to exactly what your training is, and it should be completely personal. Unless it's every day with your training and then related to that it's pointless (Athlete 2, Focus Group 5)		
"I think just because of the limited time the nutrition support is quite generic... it is better to have a bit more input on an individual basis" (Athlete 2, Focus Group 1)	*Limited contact time (n = 17)*	
"It would be great if you had an app where you could write 'right, this is what I'm doing this week, we are on our training programs' and then if they said 'right, this is how many macros you need' or whatever, for that workout for that day and week and if you're not doing that much, 'this is how much, how many calories you need and have it all been broken down'. So, flipping it on its head with inputting training and then knowing what to eat" (Athlete 5, Focus Group 1)	*Periodised and personalised nutrition plans (n = 36)*	Tailoring Technology *(n = 54)*
"Even in an app, inputting a bit of personal information would be useful, so you can actually track your weight and record things so you can see if it is actually making a difference...So say if you are 70kg on this date and you use this and you can actually see a difference, 'oh I'm actually 68.4 now' and you can see that" (Athlete 2, Focus Group 6)	*Goal setting, monitoring and feedback (n = 14)*	
"alerts and stuff like that would be helpful, different things to keep you engaged with the app. Following a path, you know, would be good." (Athlete 4, Focus Group 6)	*Notifications and reminders (n = 7)*	

"I think that an app should be in detail and might have at the start be quite simple so that everyone understands and then maybe underneath you might have the more complicated details of it because if you really know what you want to do or what you're eating things for then that would be the reason why." (Athlete 2, Focus Group 7)	*Performance focused content (n = 8)*

Theme 1: Communication strategies and information delivery

Athletes discussed a range of communication strategies employed by sports nutritionists to deliver information. The strategies described included a range of traditional nutrition education methods such as group presentations. To illustrate, Jill shared how *"the nutritionist gives us as Powerpoint on the basics we need to know, like carbs, the intakes and stuff"*. The delivery of these presentations appeared to be more front loaded in the athletes sporting calendar year as exemplified by Richard who highlighted how they "*had some nutrition at the start of the year on training camp, we did some tests and went over a few things there in a bit of a presentation and a similar thing in February, and it's just mainly going through what you'd do on different days in terms of how much training you're doing".* However, athletes did convey frustration towards the content delivered during their discussions, for instance Pete acknowledged that what they were receiving was *"the same Powerpoints that we've been seeing for quite a few years"* whereas Ben described the content as *"just very basic".*

The focus groups also generated patterns of talk around the athlete's individual experiences of one-to-one nutrition consultations. Monica described how *"they (the nutritionist) were thorough so that's why the contact time wasn't regular, because you did take away quite a lot of information from one, but it was sometimes a bit overwhelming".* Some athletes highlighted the triggers that lead to a consultation, for instance Mike said *"if you ask to see the nutritionist, it's whenever you're injured. They'll say, "we'll have a little meeting" but then they'll give you stuff and I think everyone had a meeting in pre-season to go over everything".* However, the frequency of the consultations appeared to vary between groups, as well as within groups year to year. Josh shared how "*the nutritionist is here most of the time, but I probably only really speak to them seriously about nutrition maybe once every 3 weeks"* before elaborating how this was an improvement from the previous year when *"last year you could have not really had a proper conversation for a couple of months at a time"*. Similar to Josh's current experience, Julie also shared how "*the nutritionist is not in all the time but when they are in, it's like once a week...I say, we have a meeting once a month".* Emily described some potential barriers that may be limiting athletes' one-to-one consultation opportunities:

> *"the nutritionist is available to talk to but obviously it's limited contact time. They give us talks when we're in (international) camp... they're not always at every camp. And obviously if they're there and everyone's trying to get some input from them, you can't sit down for an hour and discuss things".*

Notably, some athletes experience support via unstructured and informal conversations (commonly known in the domain as "corridor conversations"). This approach was a particularly valuable communication strategy that enabled the athlete to share and receive information quickly. To illustrate, Frank shared:

> *"I think by having a nutritionist here all the time is easier because then you can just grab them in passing and be like 'this is what I've eaten. Quite often when I weigh in, in the morning we'll chat about what I've eaten over the last day and why I'm heavy or*

why I've lost weight and where I can look at targeting to help put that on. I think that's been really good".

In addition to face-to-face methods of communication, several digital strategies were also described by the athletes, of which the use of WhatsApp was the most discussed. For example, Monica shared how *"having WhatsApp conversations are handy because you can literally send a picture or have a chat about a recipe or something quite quickly".* This ability to get feedback quickly was also highlighted by Jack who shared *"if we've got a question the nutritionist will reply within an hour or something".* In addition, Roy described the level of support being provided by sports nutritionists over this particular digital platform *"WhatsApping, there's loads and loads of nutrition support".* Mike further elaborated on this to illustrate how practitioners were using this communication channel in their applied practice:

> *"There's a WhatsApp group for nutrition…the nutritionist will put loads of stuff in, like some days they'll say there's going to be an update on what's going to be in the canteen that day, on what type of thing you can eat and what type of day you've had* and *if there's a game they'll say what you should be eating".*

However, WhatsApp was not the only digital platform described as being used by sports nutritionists to deliver information to athletes, for example Josh tell us how they *"spoke to the nutritionist on Instagram and got a few things which I felt like I was lacking"* before further detailing how their increased likelihood to engage with this content in comparison with email *"I think there will be more chance of them picking it up than an e-mail".*

Non-social media digital communication strategies were also described by athletes as a means to receive feedback from the nutritionist. The use of a range of purpose-built nutrition apps and how the athletes engage with them was described by Rachel:

> *"We used an app (Meal Logger) which I took pictures of my food and we'd send it to the nutritionist every day. The nutritionist was just seeing how I was eating, what I was eating, when I was eating and then I'd use another app (MyFitnessPal) which scanned bar codes of whatever you were eating and whatever you were making and you'd put it in and it'd count your calories".*

These experiences and insights from athletes illustrate the variety of methods employed by the modern sports nutritionist in an attempt to communicate with, and deliver information to, the athletes they may be working to support.

Theme 2: Acceptance and adoption of the online practitioner

Some athletes described how the nutrition support they now receive from a practitioner had moved to more of an online format. For instance, Susan said *"it (the nutrition support) was basically working so that I could get in touch with the nutritionist over WhatsApp if I had any concerns"*. This remote online approach was deemed useful by athletes, as illustrated by Elizabeth, *"the nutritionist is always at the end of a phone or a WhatsApp, which is really handy"*. Athletes highlighted the increase in accessibility as a potential driver of this uptake, as discussed by Richard saying, *"I think using apps are ideal really because everyone's on their phone aren't they".* Some athletes also suggested this remote service can solve logistical issues athletes face and be complementary to on-site support. Typifying this is Josh:

> *"I think, in passing it's easy at the club but having an app is much easier. You can just be like, 'boom' rather than be like 'come and I'll see you at this time' and you're 'well actually I can't see you at that time' or you've got to change everything around it. It's hard enough anyway when you're trying to book in to see a coach or something"*

The types of interactions athletes had with practitioners and the resources they received via digital platforms varied amongst the athlete groups. Some athletes detailed more of a check-in support service, such as Monica who said, *"we've had WhatsApp conversations when I've been in America, just to check, on a few of the things that we've agreed to do".* Others highlighted how the online environment has become more of a document sharing platform, as discussed by Emma, *"We've had stuff sent on WhatsApp which helps…PDF documents and nutrition plans".*

However, despite the widespread acceptance and adoption across the majority of the athlete groups, access to online support was not uniform across all sports. Despite an appetite for the online service, some focus group discussions identified its absence. To illustrate, Erica said:

> *"I think that online support would be a game changer… players probably do want to ask questions and if you do ask a sports scientist sometimes, they don't actually have the nutritionist answer."*

These athlete insights illustrate the general acceptance and adoption of an online practitioner service to providing sports nutrition support. However, the delivery of service to athletes currently appears to vary greatly.

Theme 3: A personalisation problem

Athletes described a lack of personalisation in the nutrition support they received both in person and digitally. For example, Rachel described how *"it (the nutrition support) was only in terms of ideas really, but it's not really player specific stuff"*. This experience was consistent across the groups and is further illustrated by Jill who described how *"there's a basic structure there but there's nothing, I wouldn't say, in-depth or anything"*. Some athletes described this absence of personalisation in more detail and highlighted areas that they perceived could add value. To illustrate, Charlie discussed the usefulness, and absence of, receiving individualised macronutrient requirements and targets *"I follow a macro specific diet and found that really worked but we don't get offered anything in that much detail"*. Not all athletes described a need for this level of detail but there was strong agreement that some level of tailored nutrition planning would be valuable. Exemplifying this is Ross who said, *"If you could narrow it (a nutrition plan) down to your personal needs then it would be beneficial"*.

This overall absence of personalisation led to significant frustration in a number of athletes and led them to question the usefulness of this generic approach to service provision. To illustrate Jack said:

> *"I think what the nutritionist does is pretty much pointless I'd say. It should be related to exactly what your training is, and it should be completely personal. Unless it's every day with your training and then related to that, it's pointless".*

These comments demonstrated an understanding from the athletes of why the nutrition support they receive may be the way it is currently. Most notably, athletes suggested that the problems they identified may be the result of limited practitioner contact time. For instance, Emily acknowledged that *"because of the limited time, the nutrition support is quite generic"* as well as highlighting the part time nature of the sports nutrition service provision *"They give us talks when they're (the nutritionist) in camp…they're not at every camp"*. Judy revealed other reasons why contact time maybe limited, suggesting that the problem stems from having to service large squad numbers *"I think it's hard because the nutritionist has got to do the whole squad so they can't just individualise it for everyone"*. This resonated with other athletes and is described by Ben who said, *"you can't individualise for all of us"*.

The combination of limited contact time and an absence of personalisation resulted in some athletes taking matters into their own hands as described by Mike, "*If I had to know something, sometimes I just Google it and get the answer quite easily"*. These experiences of the athletes illustrate not only the challenges they are facing as individuals, but also the practical issues facing practitioners, such as time and scale.

Theme 4: Tailoring technology

Athletes described a desire for technology that could tailor their nutrition according to their training demands. For instance, this was highlighted by Charlie who said:

> *"It would be great if you had an app where you could write 'right, this is what I'm doing this week, we are on our training programs' and then if they said 'right, this is how many macros you need' or whatever, for that workout for that day and week and if you're not doing that much, 'this is how much, how many calories you need and have it all been broken down'. So, flipping it on its head with inputting training and then knowing what to eat"*

This resonated with Phoebe who shared *"What would be cool is if you could do something based on what training you put in and what you should be eating"* before further elaborating to say why they felt this should be the preferred approach, *"because some days you double run and some days you do gym sessions and running and it's, the sports are different as well."* There was strong agreement for this rationale among the athlete groups. Typifying this was Ben who highlighted that their nutrition needs *"depends on how active we are"*.

Periodised and personalised nutrition planning

The athletes drew on their previous experiences and exposure to nutrition interventions to guide suggestions for the technology that they believed would be beneficial. The most prevalent suggestion that echoed throughout the majority of the athlete groups was the usefulness of periodised and personalised nutrition planning. To elaborate, Frank said:

> *"Those carb periodisation frameworks would be useful and I think with recipes that go with it. So, if you are saying something like a low carb or something like that, just be like 'this is a great option, this is easy to do, boom, there's the recipe".*

Notably, some athletes described how in the future this type of technology may be available to empower them, as illustrated by Barry saying:

> *"Maybe someday I'll probably be using an app just to, you know, because you can see, if you've had a hard day, what you could see what sort of things you should eat. You just give it the information and it makes a decision for you".*

Athletes also described how these periodised plans could be made more interactive to supply them with more recipe ideas, such as Emma who said, *"you can link a colour coded plan to a video of a high carb meal that you could have match day -1 or something".* This simplicity of delivery using colour coding was highlighted as being important and is discussed by Amy, *"It seems easier if you know what colour food you are".* Athletes drew reference to other technologies they currently use to illustrate the value of a solution with a simple design, as described by Richard:

> *"The thing I find quite important, and I think Training Peaks do that quite well, when you've got your week up and then you can have a look at a weekly snapshot and stuff. So yeah, I suppose the layout is quite important (for nutrition plans)".*

Performance focused content

Athletes described a need for content that could provide a rationale for their plan. Elizabeth discusses this saying *"I would like to have a bit of a reason why you're doing the nutrition plan".* Some athletes commented that technology that could deliver this performance focused content would help drive their engagement with nutrition. For example, Joey shared:

> *"I bet there's loads of knowledge out there that certain foods help you in different situations, 'if you're sore this food will help me for this', 'I've got a really hard training session coming up, I need to be lighter', 'this would be the correct food to have', do you know what I mean? If an app had that sort of knowledge, I would use it every single day, yeah, every day".*

The focus group discussions generated patterns of talk around this need for supporting information which could help provide clarity and confidence in their proposed nutrition plan.

Feedback loops

The ability for technology to support self-monitoring was also suggested as being useful. Athletes described how these features could provide feedback loops that would enable them to quantify their progression or regression. Charlie illustrates this point when discussing tracking weight related data:

> *"Even in an app, inputting a bit of personal information would be useful, so you can actually track your weight and record things so you can see if it is actually making a difference...So say if you are 70kg on this date and you use this and you can actually see a difference, 'oh I'm actually 68.4 now' and you can see that".*

Again, athletes drew on their experiences with previous technology to describe how these features may be presented visually. Jack shared how, similar to Training Peaks, *"you can have graphs and see how're you're doing"*. A range of feedback loops were identified in discussions with athletes and included monitoring adherence to a nutrition plan, sometimes by tracking macronutrient intake, as well as tracking progress against a goal or a challenge which may or may not be weight related.

Nudges

Athletes discussed how technology features such as notifications or nudges could help to support their engagement with technology. Exemplifying this is Chandler who said *"alerts and stuff like that would be helpful, different things to keep you engaged with the app. Following a* *path, you know, would be good".* Similarly, Josh shared how notifications may help to prompt behaviours such as cooking:

> *"I think, to be honest, maybe, for me, a reminder, you know it could notify you because, like on days off especially, I can go through and I can be hungry but not cook because I can't be bothered to get out of bed and that's genuine".*

These athlete experiences and insights help to illustrate the desire for a nutrition tailoring technology, as well as provide insight into what sort of features a potential future solution may have.

4.4 Discussion

This study used qualitative research methods to explore athletes' experiences and opinions of communication strategies in applied sports nutrition, as well as their suggestions for future mobile app supportive solutions. The findings revealed that athletes experience a hybrid human-computer approach to nutrition support from practitioners. Group presentations, one-to-one consultations and "corridor conversations" were the most prominent in-person communication strategies employed by sports nutritionists, although the frequency of these events and athletes' satisfaction appeared to vary. Digitally, the use of social media platforms and mobile applications was common across the majority of group as athletes accepted and adopted the online practitioner. Additionally, it was identified that athletes perceived a lack of personalisation and expressed a desire for individual tailoring in the applied sports nutrition support they currently receive. Finally, a desire for tailoring technology that could provide athletes with periodised nutrition plans tailored to the demands of their training and competing, performance focused content, feedback and nudges was also reported.

This research is the first to identify that elite athletes, across a variety of sports, perceive a lack of personalisation in the applied sports nutrition support they receive. Findings outline a desire among athletes for more tailored nutrition provision. This is consistent with the demands of the general population who report a need for more individualised nutrition care in clinical settings (Sladdin *et al.,* 2017). Despite this desire, the majority of research efforts in sports nutrition to date have focused on increasing our understanding of how nutrient availability modulates metabolism and physiology (Jonvik *et al.,* 2022). These efforts have led to the growth and evolvement of strategies such as nutritional periodisation which has rapidly become a hot topic in sports nutrition literature (Burke & Hawley, 2018; Stellingwerff *et al.,* 2019; Jeukendrup, 2017). However, the optimal delivery of such a nuanced intervention that requires a practitioner to be adequately trained in the physiology of training has yet to be explored. As this area has yet to be investigated in sports nutrition, the possibility and potential of delivering the athletes desired level of personalisation is unknown. As a result, what athletes want and what practitioners can deliver may require further attention and more critical thought.

In contrast to sports nutrition, clinical fields of practice, such as obesity and diabetes management, have dedicated time and resource to improving the design and delivery of tailored interventions and "precision" initiatives that utilise technology to progressively move towards patient support that is more individualised, contextualised and timely (Chevance, Perski & Hekler, 2020; Thomas *et al.,* 2020). These personalised interventions have been shown to produce significantly stronger health outcomes in both general and clinical populations across a range of variety of health behaviours including, but not limited to, diet and nutrition when compared with more static traditional approaches (Craig *et al.,* 2021; Wang, & Miller, 2019). To elaborate further, the athletes in this research describe the frequency at which they speak to a nutritionist "*seriously*" as every 3-4 weeks, yet also highlight that they communicate with their practitioners informally and/or digitally on a more frequent basis in an attempt to get feedback or request a resource. In these scenarios data is harvested by practitioners from a single timepoint (e.g. during a conversation, or via a series of WhatsApp messages, etc) as they make a static assessment and determine *how* or *what* is delivered. These decisions often rely on tacit knowledge which can vary from practitioner to practitioner depending on their level of applied experience, as is the case with other fields of practice (Gertler, 2003). As a result, these static approaches may be subject to high degrees of variability between practitioners. Although standardising training may help reduce this variation it is unlikely to compensate for the multiple additional years of applied experience a senior practitioner may have over a neophyte practitioner. However, technology enabled interventions, such as adaptive and continuous tuning interventions, have shown promise to support a more dynamic approach, where data can be harvested from multiple timepoints to feed algorithms that refine the intervention content, delivery or timing to the idiosyncrasies of an individual (Almirall *et al.*, 2014; Chevance, Perski & Hekler, 2020; Hardeman *et al.*, 2019; Huckvale *et al.*, 2019). These novel and emerging methodologies may now provide sports nutrition academics and practitioners an opportunity to optimise the tailoring of communication and intervention delivery strategies and become "early adopters" of technology advancements that may accelerate the evolvement of their hybrid human-computer approach (Dearing & Cox, 2018; Huckvale *et al.*, 2019; Nahum-Shani *et al.*, 2017).

The findings of this research also identified that, despite practitioners now being available to communicate with athletes online as well as in person, athletes perceived that practitioner time and resources may be spread too thinly across organisations and be a contributing factor to the lack of personalisation they experience. These suggestions are corroborated by Study 1 which found that, on average, sports nutritionists reported working across three different sports reflecting the part time and consultancy nature of the profession. An industry shift towards more full-time sports nutrition employment may support an improvement with this situation, however more full-time roles alone will not completely resolve this issue as a single practitioner can still face squad sizes of up to 64 individual athletes in one organisation, as demonstrated by the UK's rugby union premiership in 2019-20 (Shaw, 2019). Sports nutrition may now need to solve for scale and consider implementing solutions that have the potential to reach large numbers of people in a time and cost-effective manner to support practitioners, similar to other sectors of the healthcare industry where mHealth initiatives have transformed clinical practice (Steinhubl *et al.,* 2015; Vandelanotte *et al.*, 2016). Deloitte (2020) highlighted that digital technology solutions led to a 60% reduction in paperwork time and a 29% increase in patient face time for community nurses, as well as cost savings of 40% compared with usual care within the UK National Health Service. These trends are consistent across the modern healthcare system as it transitions to one that is more participatory and personalised (Goetz & Schork, 2018; Johnson *et al.,* 2020). These advancements in scalable technology solutions rely on algorithms that follow a set of processes to achieve a certain result. Given this, perhaps a consideration for sports nutritionists now is to identify what of their roles may be best suited to being outsourced to technology and what remains heuristic thinking. It is worth noting, however, that as these questions are answered and the advancements in implementation science are applied, sports nutritionists' traditional roles may be modified and new opportunities for employment may arise within this space (Masys, 2002).

Although technology appears to hold multiple potential communication and intervention delivery solutions and opportunities for athletes and practitioners, proceeding with an agnostic view may be best suited to the rapidly evolving digital landscape. How, when and where an individual's physiological data can now be captured, interpreted and returned is no longer limited to lab-based settings (Plews *et al.,* 2017; Falter *et al.,* 2019; Miller *et al,* 2021). Instead, mobile phones, smart watches and biometric rings (e.g. Apple Watch, WHOOP and Oura Ring) are now demonstrating efficacy in the remote capture of continuous data and the delivery of app-based interventions that leverage principles from health behaviour theories to improve health and performance behaviours, such as sleep (Reeder & David, 2016; Browne *et al.,* 2021). These experiences are currently limited by hardware, e.g. mobile phones, however the development of web 3.0, augmented reality and the metaverse may create new highly immersive environments for practitioners to create, share, educate and influence through virtualisation (Kye *et al.,* 2021). Echoing the work of Jonvik and colleagues (2022), it does appear applied sports nutrition is at a critical juncture in its evolution and is primed to utilise new technologies to support athletes.

4.5 Conclusion

These findings advance our understanding of the current issues surrounding communication strategies in applied sports nutrition, as well as identifying future opportunities for mobile apps to support practitioners' service provision. Specifically, this study identified that athletes experience a hybrid human-computer approach to nutrition support that they perceive lacks personalisation from practitioners. In addition to increasing practitioner knowledge, time and availability to address this problem, additional research efforts focusing on ideating and developing technology that can help automate certain sports nutrition tasks may be worth exploring to help practitioners scale their service delivery in a time and cost-effective manner. During these processes it is recommended that that the acceptability of any novel applications, as well as athletes' engagement with these technologies, is explored (Perski *et al.,* 2016; Perski & Short, 2021).

4.6 Reflections on the Research Journey: Expectations vs Reality

My background as a sports nutrition practitioner was something I valued throughout the process of Study 2. Had I been solely in academia and not split across both applied practice and research activities I think I would have struggled more with the access required to some of the world's top athletes. On paper, recruiting participants of that calibre across a range of sports and from both genders can be a difficult process. However, being a practitioner with a strong network of supportive colleagues, many of whom have been on their own PhD journeys, proved beneficial. In addition to the peer support that was becoming apparent during the recruitment phase, there was a genuine interest in the research from other practitioners to understand more about the potential implications that digital technology could have for their applied practice. Throughout the various phone calls and emails with gatekeepers to explain and arrange the focus groups, it became apparent that "FOMO" (fear of missing out) was a factor driving the appetite for the topic area within the sports nutritionist community.

Once organised, the athlete focus groups were an incredibly enjoyable process. During these focus groups, I uncovered some forthright opinions of how they felt about the sports nutrition support they had received, as well as what they believed they should be receiving. It became apparent to me early that my position as a practitioner with an understanding of what happens "behind the curtain" in the world of professional and elite sport helped me probe the athletes effectively and glean raw and unfiltered insights from each focus group. During the analysis of the focus groups, I was initially taking aback by how empathetic some athletes were towards the constraints placed on their sports nutritionists. Perhaps the reason this shocked me was that maybe I unconsciously thought athletes wouldn't notice these things. Regardless of the empathy some showed it was evident from the findings that athletes still desired a higher level of personalisation than what they were currently receiving. It began to seem as though there was gap between the expectations of athletes and the reality of what sports nutritionists were capable of delivering. At this moment I felt like the privileged and honest insights from athletes in Study 2, combined with those already gathered from practitioners during in Study 1, were beginning to generate ideas that I was excited to explore in Study 3.

Chapter Five:

Study 3: Using Behavioural Design Thinking to develop and pilot a personalised sports nutrition digital behaviour change intervention for athletes

STUDY MAP

STUDY AND AIMS	OBJECTIVES	OUTCOMES
STUDY 1 Explore how social media mobile apps are being used by sports nutritionists as part of service provision to athletes, as well as capture their experiences and opinions of its use.	• Determine the prevalence and perception of social media usage by sports nutritionists in practice. • Identify current platform usage, as well as the type, frequency and format of content delivered. • Establish sports nutritionist perspectives on digital training. • Establish sports nutritionists' experiences and opinions of social media use as part of service provision.	• Widespread use of social media and perceived as beneficial. • Multiple platforms used for varied content delivery. • A lack of and desire for training for digital interventions. • Embraced as an extension of service provision.
STUDY 2 Explore athletes' experiences and opinions of communication strategies in applied sports nutrition, as well as their suggestions for future mobile app supportive solutions.	• Obtain athletes' opinions of contemporary communication strategies in applied sports nutrition. • Establish potential problems and opportunities relevant to the development of a DBCI. • Identify athletes' suggestions for future mobile app supportive solutions.	• Infrequent 1-2-1 and group consultations but an acceptance and adoption of the online practitioner. • Lack of personalisation and limited contact time prevalent. • Desire for tailoring technology.
STUDY 3 Using Behavioural Design Thinking to develop and pilot a personalised sports nutrition digital behaviour change intervention for athletes	• Identify target behaviour and behaviour change requirements for athletes. • Map requirements to theoretical behaviour change model to ground in behaviour change science. • Ideate and design mobile app DBCI features. • Pilot and preliminarily evaluate the personalised sports nutrition mobile app DBCI with athletes.	

5.1 Introduction

Athletes are a unique population with specialised nutritional needs (Thomas, Erdman & Burke, 2016; Burke & Hawley, 2018). An athlete's diet requires a high degree of personalisation on a daily basis to maintain health and enhance performance (Thomas, Erdman & Burke, 2016; Close *et al.*, 2016; Fahrenholtz *et al.*, 2018; Burke & Hawley, 2018). The type, timing and total amounts of food and drink that athletes consume can have a profound impact on their ability to perform during, recover from and adapt to training and competition events (Jeukendrup, 2017; Impey *et al.*, 2018; Stellingwerff, Morton & Burke, 2019). Given the periodised and dynamic nature of an athletes training and competition schedule, their individual dietary requirements can vary greatly from day-to-day, as well as within day, in line with the demands of the exercise stimulus, the desired training outcome and the time available for recovery (Stellingwerff, Boit & Res, 2007; Stellingwerff, 2012). Delivering a high degree of personalisation can be challenging for the sports nutrition practitioner who, on average, typically works across three different sports and can work with squad sizes in excess of more than 60 individual athletes in a single organisation (Shaw, 2019). Challenges of time and scale have been by highlighted by practitioners (Study 1), and athletes (Study 2) whom have suggested such limitations are a contributing factor to a lack of personalisation in the nutrition support they experienced.

Global technology trends may provide new opportunities for practitioners to provide digital support to athletes. Both owning a smartphone and using mobile apps have been ubiquitously accepted as the norm with 86% of the global population now owning a device where the general population typically spend an average of 3-5 hours a day using mobile apps (Sydow, 2020; Ericsson, 2021). Each smartphone owner has been shown to use 10 mobile apps per day, and 30 apps per month to help manage their lives (App Annie, 2017). These mobile apps can serve as portable tools for the delivery of easily accessible, scalable and cost-effective health and wellbeing interventions, often referred to as mHealth (Klasnja & Pratt, 2012; Coughlin *et al.,* 2016; Ben-Zeev *et al.,* 2021; Iribarren *et al.,* 2017). Many of these mHealth tools are now powered by artificial intelligence (AI) (Bhatt *et al.,* 2022). These AI capabilities enable the technologies to perform cognitive functions that we normally associate with human intelligence, such as perceiving, reasoning, learning, interacting with the environment, problem solving, decision-making, and even demonstrating creativity (Collins *et al.,* 2021). It is generally believed that AI will help to facilitate and enhance human work (Bohr & Memarzadek, 2020).

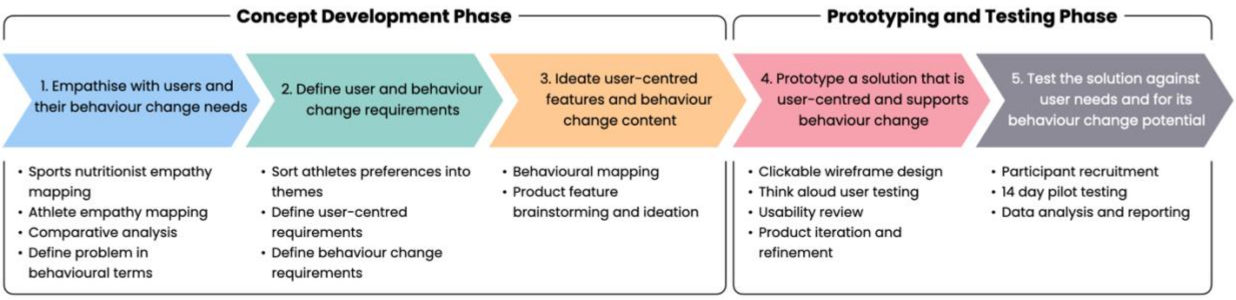
DBCIs (see **2.6**) that employ these mobile technologies to deliver behavioural modification interventions have become increasingly popular due to their potential to improve the reach and efficiency of health support (Michie *et al.,* 2017a; Murray *et al.,* 2016; Kay *et al.,* 2011; Marcolino *et al.,* 2018). The integration of behavioural science can be complemented by design science to help support the development of more engaging mHealth technologies (McCurdie *et al.,* 2012; Yardley *et al.,* 2015). Behavioural design (see **2.5**) and design thinking (see **2.7**) have each emerged as best practice approaches in their respective fields. Recently it has been recommended that both behavioural design and design thinking are to be used in conjunction with each other, referred to as Behavioural Design Thinking (see **2.8**), throughout the DBCI design process to balance user-stated preferences with evidenced-based behaviour change strategies (Voorheis *et al.,* 2022).

The aim of Study 3 was to use a Behavioural Design Thinking approach to synthesise the findings from Study 1 and Study 2 and generate ideas for, as well as design and pilot, an innovative personalised sports nutrition mobile app DBCI for athletes.

5.2 Methods

The Behavioural Design Thinking approach used in this current study, which combines both the behavioural design and design thinking frameworks outlined previously, is grounded in the work of Voorheis and colleagues (2022). This approach, illustrated in **Figure 9**, is comprised of five steps: (1) empathise with users and their behaviour change needs; (2) define user and behaviour change requirements; (3) ideate user-centred features and behaviour change content; (4) prototype a solution that is user-centred and supports behaviour change; and (5) test the solution against user needs and for its behaviour change potential. Steps 1-3 comprise the Concept Development Phase, whereas steps 4-5 encompass the Prototyping and Testing Phase.

Figure 9. A Behavioural Design Thinking approach to sports nutrition DBCI design.



Step 1. Empathise with users and their behaviour change needs.

The outcomes of the sports nutritionist surveys and interviews, as well as the athlete focus groups, from Study 1 and Study 2 of this present thesis were analysed to create empathy maps for both sports nutritionists and athletes (Gray, Brown & Macanuflo, 2010; Siricharoen, 2021; Buchheit & Allen, 2022). A comparative analysis was performed between the two empathy maps to identify patterns of similarities and differences (Given, 2008). These patterns were used to develop a conceptual model of the possible problem, and opportunity, between the two populations. The problem was defined in behavioural terms which involved identifying: 1) who is performing the behaviour and 2) what the behaviour is (Atkins & Michie, 2015).

Step 2. Define user and behaviour change requirements.

Empathy maps and the behaviour change needs were analysed to define the user requirements. High-level user-centered requirements were identified by sorting athletes' preferences into key themes to be addressed. Behaviour change requirements were defined by: 1) selecting the target behaviour; 2) specifying the behaviour targeted for change; 3) understanding the target behaviour and identifying what needs to change (Atkins & Michie, 2015). *Selecting the target behaviour* involved generating a list of the potential behaviours that may be relevant to the problem that is being solved for, as well as considering the impact and likelihood of changing the behaviour. To *specify the behaviour* the researchers identified: i) who needs to perform the behaviour; ii) what the person needs to do differently to achieve the desired change; iii) when they will do it; iv) where they will do it; v) how often they will do it; vi) with whom they will do it (Atkins & Michie, 2015). Understanding the target behaviour and identifying what needs to change was done by performing a behavioural diagnosis utilising the COM-B model and TDF (Atkins & Michie, 2015).

Step 3. Ideate user-centred features and behaviour change content.

The researcher used behavioural mapping to: i) identify intervention functions; ii) identify policy categories; iii) identify BCTs using the Theory and Techniques Tool (Human Behaviour Change Project, 2016); and iv) identify mode of delivery for the intervention. Concurrently throughout this process, the researcher collaborated with a design team, technology team and performance science team to ideate user-centred product features. The design team was comprised of a user experience and interaction designer, behavioural scientist and senior creative. The technology team was comprised of a senior full-stack software engineer, solution architect and data scientist. The performance science team was comprised of multiple performance nutritionists and exercise physiologists. Together this multidisciplinary team brainstormed user-centred features and specified how the requirements could be operationalised within a mobile app DBCI.

Step 4. Prototype a solution that is user-centred and supports behaviour change.

Clickable wireframe prototypes were designed using Figma software (version 116.5.18). These prototypes were user tested utilising think aloud protocols (de Jong, 2005) with design improvements and refinements made throughout the process. Notes from user testing sessions were reviewed in-line with Nielsen's usability attributes of systems acceptability (Nielsen, 1993), a framework used to help iterate and refine user journeys and user interfaces, as well as identify areas for future product improvements.

Step 5. Test solution against user needs and for its behaviour change potential.

A personalised sports nutrition mobile app DBCI for athletes was developed and piloted for 14 days to identify early positive or negative signals for its behaviour change potential, understand initial app uptake (Baumel *et al.*, 2019) and align with the high-performance sports organisation training calendar. A 14-day pilot period was selected to ensure the results were comparable to mHealth industry standards of objective user engagement and retention (Baumel *et al.*, 2019). An invitation to take part in this research was shared with, and accepted by, a high-performance sports organisation in Ireland. A practitioner from within the organisation's performance support team volunteered to act as the gatekeeper. This gatekeeper invited the athletes from within the organisations men's senior squad to volunteer to participate. A total of 26 volunteered before they were prompted to download the mobile app. Participants met the following inclusion criteria: i) >18 years of age; ii) were classified as tier 3 or above according to the 6-tiered Participant Classification Framework, and iii) do not have or have not previously suffered from an eating disorder or disordered eating (McKay *et al.*, 2022). No formal training was provided to the athletes on how they should use the mobile app. However, once the athletes created an account, they did receive a "Welcome Pack" via email which provided some brief information about each of the product features. The mean age of participants was 25 (SD = 4) years. Following Step 4, it was determined that participants planning of training sessions in the app to generate personalised and periodised nutrition plans, as well as app usage engagement metrics on both training and non-training days, would be used to evaluate the interventions behaviour change potential. Specifically, the amount, frequency, duration and depth of usage were measured (Perski *et al.,* 2017). The pilot testing component was granted ethical approval by the University Research Ethics Committee at Liverpool John Moores University (20/NSP/027).

5.3 Results

Step 1. Empathise with users and their behaviour change needs

Practitioner and athlete empathy maps were developed and can be seen in **Figure 10** and **Figure 11** respectively. The comparative analysis identified a fundamental mismatch between what practitioners report they are currently capable of delivering and want athletes describe they need. Conceptually, the problem identified was that practitioners are unlikely to be able to deliver the scalable, continuous and personalised planning service that athletes desire due to limitations in training and time; and the opportunity was that athletes could be empowered with a scalable, continuous and personalised digital planning tool that meets their needs whilst protecting practitioner time and reducing practitioner training requirements. Defined in behavioural terms the problem was *"athletes are not planning their daily individual daily energy and macronutrient needs in accordance with the demands of their training and competition schedules"*.

Figure 10. Sports nutrition practitioner empathy map.

Figure 11. Athlete empathy map.

Step 2. Define user and behaviour change requirements

The target behaviour selected, and its specification, are presented in **Table 8**.

Table 8. Target behaviour selected and its specification.

Target Behaviour	**Athletes create a daily personalised & periodised nutrition plan in accordance with the demands of their training & competition schedules**
Who needs to perform the behaviour?	Athletes
What do they need to do differently to achieve the desired change?	i) They need to know how to create a personalised and periodised nutrition plan. ii) The need the opportunity to access nutrition support 24/7 to create and amend their personalised and periodised nutrition plans. iii) They need to think that the creating a plan is simple and not time consuming. iv) They need to be motivated enough to create a personalised and periodised nutrition plan. v) They need to be confident in the accuracy of personalised and periodised nutrition plans they create. vi) They need their plan to align with their performance goals.
When will they do it?	*For Training:* At any time-point before their first meal/snack of the day that the training event is occurring on. *For Competition*: At least 36 hours before the competition event.
Where will they do it?	Anywhere as long as they have access to the intervention via a smartphone and WiFi.
How often will they do it?	1-7 times per week depending on how far ahead they choose to plan.
With whom will the do it?	On their own.

A behavioural diagnosis, expressed using the COM-B model and TDF, is presented in **Table 9**.

Table 9. Behavioural diagnosis and mapping using the Behaviour Change Wheel, Theoretical Domains Framework and Behaviour Change Techniques.

COM-B component		TDF domain	Description of what needs addressing in the intervention	Intervention Functions	Policy Categories	Behaviour Change Techniques
Capability	Psychological	Knowledge	Athletes need to know how to calculate and distribute their daily energy and macronutrient requirements according to the demands of their training and competition schedule.	Education Enablement	Service provision	2.6 Biofeedback 4.1 Instruction on how to perform the behaviour 5.1 Information about health consequences
			Athletes need to know how to translate their requirements into real food and portion size recommendations.	Education Enablement	Service provision	4.1 Instruction on how to perform the behaviour 5.1 Information about health consequences
		Behavioural regulation	Athletes need to know when to create, edit and view their nutrition plans	Education	Service provision	4.2 Information about antecedents
		Memory, attention & decision processes	Athletes need to remember to create the nutrition plan, of which the creation had to be a simple and convenient process.	Education Enablement	Service provision	1.4 Action planning 11.3 Conserving mental resources
Opportunity	Social	Social influence	Athletes need to perceive creating their nutrition plan themselves as the norm.	Modelling Enablement	Service provision	6.3 Information about others approval

	Physical	Environmental context and resources	Athletes need the opportunity to access 24/7 on-demand support to create and adjust their nutrition plan as required.	Environmental restructuring Enablement	Environmental /Social planning	3.2 Social support (practical) 12.1 Restructuring the physical environment 12.5 Adding objects to the environment
Motivation	Reflective	Social/ professional role and identity	Athletes need to believe that creating a nutrition plan is part of their role as an athlete.	Persuasion Modelling	Service provision	6.2 Social comparison 9.1 Credible source
		Beliefs about capabilities	Athletes need to believe they can make a nutrition plan that is accurate and tailored enough to their individual needs to be useful.	Education Persuasion Enablement	Service provision	4.1 Instruction on how to perform the behaviour 8.1 Behavioural practice/rehearsal 8.7 Graded tasks 13.2 Framing/reframing
		Goals	Athletes plans need to reflect the end states they wish to achieve to support performance outcomes	Incentivisation	Service provision	1.3 Goal setting (outcome)
		Beliefs about consequences	Athletes need to believe that the effort required to make the plan is for worth it.	Persuasion Incentivisation Enablement	Service provision	5.1 Information about health consequences 10.8 Incentive (outcome)

					10.10 Reward (outcome)
	Reinforcement	Athletes need to value the nutrition plans they create.	Incentivisation	Service provision	10.8 Incentive (outcome) 10.10 Reward (outcome)

Key themes to be addressed and high-level user-centred requirements are presented in **Table 10**.

Table 10. Key themes to be addressed and high-level user-centred requirements.

Theme	High-level user-centered requirements
Scalable and continuous support	• A user shall register by entering their username and password, in order to get access to the service. • A user shall engage with the service anywhere they have a WiFi connection, in order to get on-demand access.
Daily personalisation; Autonomy supportive	• A user shall add their biometric, lifestyle, meal pattern and activity data to the system, in order to build a personalised profile. • A user shall select their body composition goal, in order to tailor their energy requirements. • A user shall add sporting and training load data, in order to personalise their low, medium and high carbohydrate ranges. • A user shall add their planned daily workout information, in order to create a personalised and periodised nutrition plan. • A user shall edit their planned daily workout information as required, in order to update their personalised and periodised nutrition plan. • A user shall receive a personalised coaching insight when they create or edit their plan, in order to provide context to the plan. • A user shall view an individual meal or snack, in order to get practical food recommendations and portion size guides.

Step 3. Ideate user-centred features and behaviour change content.

The behavioural mapping of intervention functions, policy categories and behaviour change techniques can be seen in **Table 9**. A React Native mobile application, available on both iOS and Android, was selected as the mode of delivery. The use of AI was identified as a requirement to generate the personalised and periodised nutrition plans from each athlete's profile, meal pattern and workout data.

Ideated functional features can be seen below in **Figure 12**. Please note that during the ideation of these features the researcher considered not only how to target the planning behaviour outlined in this research, but also how to target a user's adherence to the plan and its associated nutritional periodisation behaviours. These primary features included a periodised fuel planner referred to as "Carb Coding", an energy and macronutrient recommender referred to as "Kcals & Macros", as well as an energy balance data visualisation feature called "Live Energy". Secondary features included portion size guides, personalised meal patterns, as well as personalised low, medium and high carbohydrate ranges.

Figure 12. Ideated functional features for mobile app DBCI.

Step 4. Prototype a solution that is user-centred and supports behaviour change.

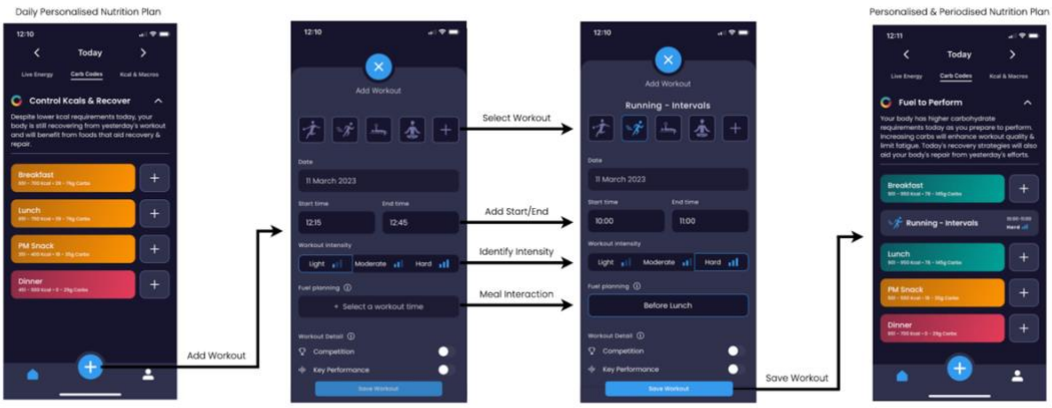
Design refinements following user testing and review against Nielsen's usability attributes of systems acceptability can be seen in **Table 11**. Additional suggestions for future improvements were also identified by users, however, these features were beyond the scope of this current project and as a result were added to the DBCI's technology roadmap for future development.

Table 11. Nielsen's usability attributes of systems acceptability and design refinements.

Nielsen's usability attributes	Design refinements in current project	Future improvements added to technology roadmap
Easy to learn	Education flow introduced during on-boarding	-
Efficient to use	-	Recurring workout option when adding a workout
Easy to remember	-	Notifications
Few errors	Clickable space of buttons increased	-
Subjectively pleasing	Design system expanded to include new colours	-

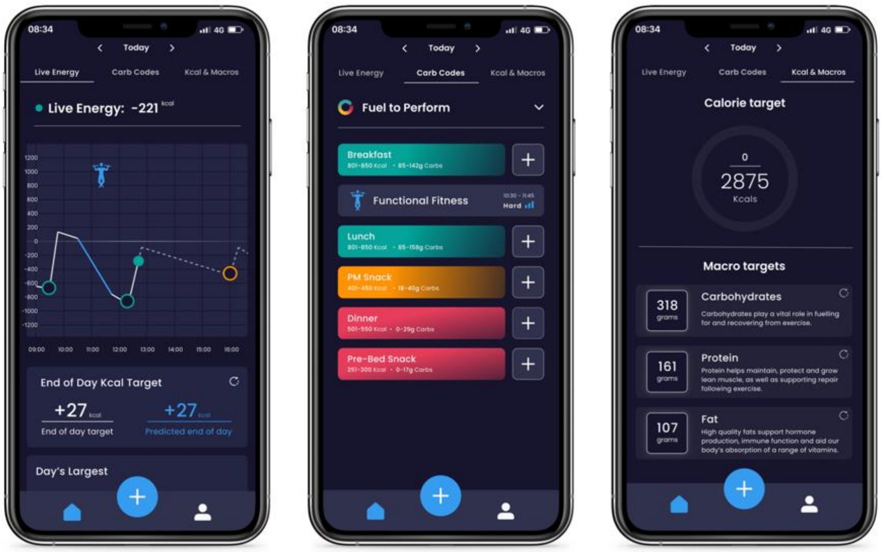
An example of the wireframes produced for individual user journeys can be seen in **Figure 13**.

Figure 13. "Adding Workouts" user journey wireframe.



The final primary mobile app user interface screens can be seen in **Figure 14** below.

Figure 14. Primary mobile app DBCI screens: Live Energy, Carb Coding, Kcals and Macros.



Step 5. Test solution against user needs and for its behaviour change potential

The participants were active on the app for a mean of 10.46 days (SD = 3.42) during the 14-day trial period. The app was utilised on 85.96% (SD = 28.26) of the participants' planned training days and 62.73% (SD = 32.53) of their non-training days. The average number of engagement sessions per day was 2.53 (SD = 1.84). The number of individual participants engagement sessions per day across the trial period can be seen in **Figure 15** below.

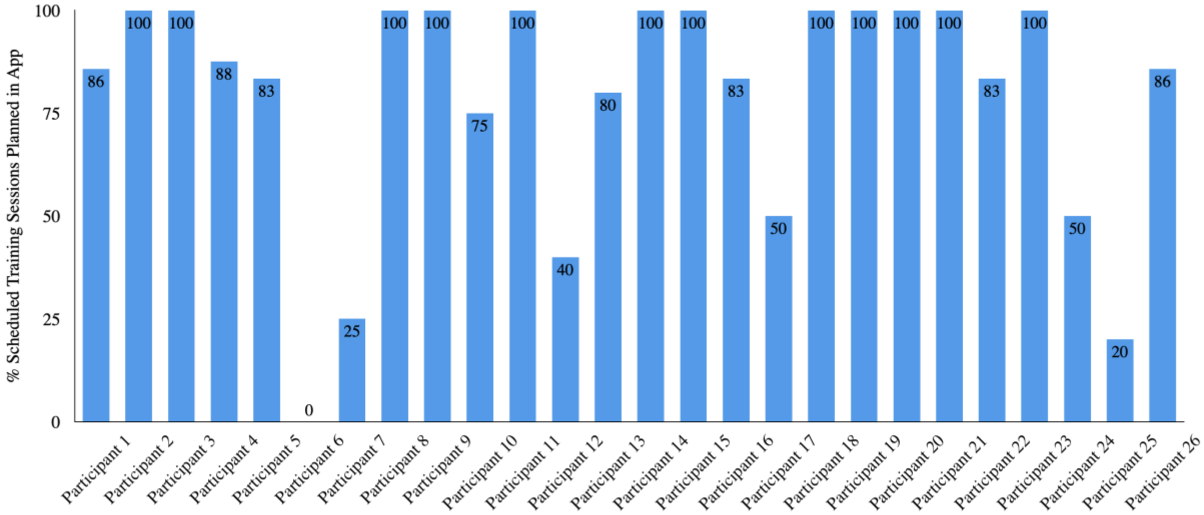
Figure 15. Individual athletes' number of engagement sessions per day.

Participant	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14
Participant 1	3	1	0	0	1	0	0	0	0	0	1	0	0	0
Participant 2	1	2	1	4	6	4	3	1	0	1	0	2	0	1
Participant 3	10	10	4	0	1	1	3	1	2	3	3	0	0	0
Participant 4	6	3	2	1	1	1	0	0	0	1	0	0	1	1
Participant 5	9	9	2	1	0	1	1	0	0	1	0	0	0	1
Participant 6	7	2	1	4	0	4	6	4	0	2	2	2	1	0
Participant 7	1	0	0	0	0	0	0	0	0	1	1	0	0	0
Participant 8	2	1	2	2	1	1	1	2	0	1	1	0	0	0
Participant 9	4	3	2	5	2	3	8	6	4	3	4	4	4	5
Participant 10	6	9	1	3	0	2	5	2	1	2	0	2	3	1
Participant 11	7	13	12	10	10	6	1	5	6	3	2	6	3	1
Participant 12	4	3	1	2	1	0	1	0	0	0	0	2	0	0
Participant 13	1	2	3	1	1	0	1	1	1	2	1	0	1	1
Participant 14	3	5	2	1	0	1	2	2	2	2	3	1	2	0
Participant 15	8	8	7	5	9	11	6	7	6	9	9	8	10	6
Participant 16	9	5	4	3	3	2	1	2	3	3	1	3	2	2
Participant 17	2	1	0	1	0	0	0	0	0	0	0	0	0	0
Participant 18	3	5	1	3	5	0	2	1	1	1	2	0	0	1
Participant 19	4	6	0	0	0	1	2	1	3	3	1	2	1	2
Participant 20	7	5	5	4	2	1	1	1	1	1	1	1	1	1
Participant 21	3	7	10	9	3	0	0	4	6	5	4	1	2	3
Participant 22	6	5	3	2	4	3	2	3	2	2	1	2	3	1
Participant 23	2	3	0	1	2	5	8	5	12	2	2	10	7	8
Participant 24	1	6	1	2	0	0	0	0	0	2	0	1	0	0
Participant 25	5	4	3	2	0	1	5	4	4	0	4	0	5	0
Participant 26	8	6	6	9	6	8	3	7	3	1	4	5	3	0

The mean amount of time each participant spent on the app per day was 3.68 minutes (SD = 2.54). To better understand the app usage after participant account creation and initial app explorations had taken place the researchers decided to exclude day 1, and the mean amount of time each participant spent on the app per day during days 2 to 14 was 2.44 minutes (SD = 2.23).

Participants planned 78.80% (SD = 29.24) of their scheduled training sessions in the app, generating personalised and periodised nutrition plans for these training days. Scheduled training sessions were verified with the gatekeeper. The percentage of individual participants scheduled training sessions planned in the app can be seen in **Figure 16** below. Rest day nutrition plans were generated by the participants for all non-training days.

Figure 16. Individual athletes % scheduled training sessions planned in the app.



5.4 Discussion

This study employed a behavioural design thinking approach to design and pilot a personalised sports nutrition mobile app DBCI for athletes. In line with the best practice recommendations on the importance of behavioural design and design thinking, a 5-step process was employed by a multidisciplinary team to design an effective DBCIs (Voorheis *et al.*, 2022). The findings revealed a fundamental mismatch between what practitioners report they are currently capable of delivering and what athletes describe they need. The solution designed was a scalable and autonomy supportive mobile app DBCI for athletes that enables them to create personalised and periodised daily nutrition plans in accordance with the demands of their training and competition schedules. Pilot testing revealed that the app, was utilised by athletes to create a daily personalised and periodised nutrition plans for the majority of their training and non-training days, suggesting that a Behavioural Design Thinking approach is an effective framework to design a mobile app DBCI for athletes.

This research is the first to identify that athletes can, when supported with a specifically designed app, effectively create daily personalised and periodised nutrition plans. These findings highlight the opportunities that theoretically designed digital technology tools can bring to sports nutrition to evolve the current solutions being experienced by athletes (see Study 2). These findings are consistent with those in clinical populations where the use of mHealth digital technology by patients has been highlighted for its potential to alleviate the clinical load of physicians whilst ensuring optimal care for patients (Ting *et al.,* 2020). It is feasible that these solutions for sports nutritionists could match those seen in healthcare clinical settings where it has been reported that healthcare professionals can now care for up to five times as many inpatients when supported with mHealth technologies (Tan *et al.,* 2023). Such improvements in efficiency can also positively impact the cost-effectiveness of technology supported clinical care (Lou *et al.*, 2022).

In contrast to other mHealth apps where the engagement tends to be poor during the initial two weeks of use, the engagement with the app explored in this current study remained higher in comparison (Baumel *et al.,* 2019; Kim, Oh & Shin, 2020). To illustrate, a Mobile Consumer Report found that for medical, health and fitness apps, typically only 20% of users will continue to use the app one day after installation, and that figure drops to 8% for those who continue to use seven days after installation (Appboy, 2016). Similarly, a panel-based analysis systematically examined usage patterns in 93 mHealth apps and found that the median app retention rate at 15 days after installation were 3.9% (Baumel *et al.,* 2019). Sinzay and colleagues (2021) provide one possible explanation for these higher levels of engagement experienced during this pilot period, suggesting that engagement appears to be primarily influenced by features that provide the user guidance, promote minimal cognitive load, support self-monitoring, provide embedded social support and support action planning, all of which were designed into the current mobile app DBCI. Another rationalisation may be that the tailoring in the app was designed to empower and meet the needs of specific user groups (Vo, Auroy & Sarradon, 2019; Köing *et al.,* 2021). However, despite positive early engagement and behaviour change signals it is important to highlight that an extended testing period may be required to better understand the longer-term trends in app uptake, usage and behaviour. Additional future explorations should aim to test the impact of including notifications on planning behaviours and app engagement (Alkhaldi *et al.,* 2016; MacPherson *et al.,* 2019; Oakley-Girven *et al.,* 2021). Although, it is worth noting that the effectiveness of such a feature may not be down to just its inclusion, but also the time and context in which the athlete receives it (Nahum-Shani, Hekler & Spruijt-Metz, 2015; Hardeman *et al.,* 2019), as well as the language used (Altendorf *et al.,* 2019). Furthermore, the inclusion of feedback loops, which have been proven effective in several health behaviour interventions such as smoking cessation, physical activity and nutrition (Annesi, J., 1998; de Vries *et al.,* 2008; Fuji *et al.,* 2009) and were suggested as a desired feature by the participants in Study 2, should also be considered for exploration and inclusion in future research and development activities. Such feedback loops may help the technology become "persuasive" and increase a user's self-monitoring, goal setting and self-efficacy by supporting the coaching role of the practitioner (van der Weegan *et al.,* 2013).

5.5 Conclusion

The bringing together of novel technology innovations with the sports nutrition knowledge milestone of periodised nutrition has the potential to empower athletes with 24/7 personalised support whilst solving the problems of time and scale for the practitioner (Jonvik *et al.,* 2022). To the authors knowledge, the personalised sports nutrition mobile app DBCI developed as part of this study is the first initiative of its kind in that it aims to deliver technology enabled scalable and continuous real-time personalised nutrition support to athletes. This study describes and demonstrates the importance of both behavioural design and design thinking in the creation of such a technology for both athletes and sports nutritionists. The design and pilot trial of the novel sports nutrition mobile app DBCI are the first steps in delivering on the personalisation expectations of athletes with an autonomy supportive solution, whilst also addressing the problems of time and scale being experienced by sports nutritionists.

5.6 Reflections on the Research Journey: New Beginnings?

In pragmatic fashion, the methodologically approach within this final study flowed from qualitative where I was attempting to constructing meaning and understanding from the findings of Study 1 and Study 2 in order to design the DBCI, to quantitative where I was ultimately seeking to establish if the innovation developed was effective. This transition in approach satisfied my desire to "see the numbers" and accommodate my inner positivist. However, there was one major challenge I had not foreseen at the start of my PhD journey as I entered into this final study, access to a "lab". Given the nature of my research I had to build my own digital lab which evolved me from a practitioner-researcher to a practitioner-researcher-entrepreneur as I embarked on a journey of raising funds to develop the proposed technology innovation in sports nutrition. Although this was not easy, I am happy with the route I chose and I hope it shows other researchers in future PhDs that there are other, albeit less well travelled paths, to contributing novelty to the discipline. Fortunately, this digital lab is now built and I would welcome other sports nutrition researchers with open arms to use the resource for future research.

One underlying personal motivation I had during Study 3 was to give a good account of my intervention design skills. For context, there was now a good awareness about the role behaviour change science could play in applied sports nutrition with many researchers actively publishing papers that were advocating for its use. Despite this, hardly anyone in sports nutrition was actually managing to design, develop and deliver such interventions. In many ways I wanted to be someone who could "walk the walk" not just "talk the talk". At this stage of my research journey, and given the breadth of new fields of practice I had been exposed to over the previous years, I had now developed into more of a "generalist". I was aware of the impact of design and a timely publication about Behavioural Design Thinking managed to tie many of the concepts brewing in my brain into a systematic process that could be employed to demonstrate the design of an innovate and theoretically driven DBCI, whilst also capturing quantitative pilot data to measure its effectiveness. I suppose you could call this an "aha" moment.

The development of the DBCI itself was probably the highlight of the research phase of this PhD for me. I wish I had learned the problem solving and invention activities exposed me to during this phase during either my undergraduate or postgraduate qualifications. I would even go as far as to say university courses should be altered to include such activities to aid the development of sports nutrition practitioners practical applied skills. I view the quantitative element of this study as the first step in the right direction. Although it has answered the initial questions outlined by the innovation research approach to this thesis by providing an advantage to athlete development and organisational performance, with a positive cost-benefit ratio, whilst also being practical, I do believe this is just the start for innovative technology research within sports nutrition.

Chapter Six:

Discussions, Conclusions and Recommendations

STUDY MAP

STUDY AND AIMS	OBJECTIVES	OUTCOMES
STUDY 1 Explore how social media mobile apps are being used by sports nutritionists as part of service provision to athletes, as well as capture their experiences and opinions of its use.	• Determine the prevalence and perception of social media usage by sports nutritionists in practice. • Identify current platform usage, as well as the type, frequency and format of content delivered. • Establish sports nutritionist perspectives on digital training. • Establish sports nutritionists' experiences and opinions of social media use as part of service provision.	• Widespread use of social media and perceived as beneficial. • Multiple platforms used for varied content delivery. • A lack of and desire for training for digital interventions. • Embraced as an extension of service provision.
STUDY 2 Explore athletes' experiences and opinions of communication strategies in applied sports nutrition, as well as their suggestions for future mobile app supportive solutions.	• Obtain athletes' opinions of contemporary communication strategies in applied sports nutrition. • Establish potential problems and opportunities relevant to the development of a DBCI. • Identify athletes' suggestions for future mobile app supportive solutions.	• Infrequent 1-2-1 and group consultations but an acceptance and adoption of the online practitioner • Lack of personalisation and limited contact time prevalent. • Desire for tailoring technology.
STUDY 3 Using Behavioural Design Thinking to develop and pilot a personalised sports nutrition digital behaviour change intervention for athletes	• Identify target behaviour and behaviour change requirements for athletes. • Map requirements to theoretical behaviour change model to ground in behaviour change science. • Ideate and design mobile app DBCI features. • Pilot and preliminarily evaluate the personalised sports nutrition mobile app DBCI with athletes.	• Nutrition planning behaviour targeted. • Theory driven and autonomy supportive personalised DBCI developed. • Athletes planned their nutrition for 78.80% of their schedule training days and 100% of non-training days.

6.1 General Discussion

The primary aim of this thesis was to design, develop and pilot a mobile app DBCI, using innovation research methods, that caters to the needs of both the athlete and the practitioner in applied sports nutrition. Following a literature review in chapter one, which detailed the factors that influence athlete's nutrition behaviours, the current state of play for behavioural interventions in sports nutrition, as well as the recent advancements in technology and resulting opportunities for the discipline, three original research studies were presented sequentially in chapters three, four and five. Each chapter sought to contribute to the overall thesis objectives by establishing the experiences and opinions of digital platform use in practice from both the perspective of a sports nutritionist as well as an athlete, as well as capturing its prevalence and suggestions for new solutions along the way, before going on to successfully design, develop and pilot a new mobile app DBCI using novel methods throughout the process. This purpose of this current chapter is to bring together, interpret and discuss the main findings of the previous three chapters. In doing this, this chapter will make connections between the individual studies and the decisions made, as well as justify the logic and flow of the research journey. The chapter will progress to draw conclusions from this body of work, highlight its strengths and limitations, before providing recommendations for both future research and applied sports nutrition practice. To close this chapter the researcher will share a short reflection on his journey and personal development as a practitioner-researcher-entrepreneur.

Given the global trends in technology discussed in both chapter one and two, Study 1 sought to determine if, how and why sports nutritionists use social media mobile apps as part of their service provision to athletes. A mixed methods approach explored the prevalence of practitioner's social media use, as well as their experiences and opinions of its use in practice. Following this rapid growth in mobile technology uptake and resulting opportunities for sports nutritionists previously discussed, interviewing practitioners and capturing their current practices was deemed beneficial in understanding the role that mobile apps were currently playing in their applied service provision, whilst also identifying any problems they may have experienced or beneficial opportunities the technology facilitated. Although involving practitioners as key stakeholders in the development of novel digital interventions has been shown to be successful in healthcare settings (Alexander, Brijnath & Mazza, 2014; Curtis, Lahiri & Brown, 2015), little was known previously from the perspective of the sports nutritionist. Healthcare settings have also demonstrated the beneficial effects of understanding practitioners' barriers and enablers related to novel intervention uptake (Alexander, Brijnath & Mazza, 2014), yet these "pain relievers" and "gain creators" which enable the creation value (Lenterink *et al.,* 2020) were also not yet known for sports nutritionists. Given this, Study 1 sought to address these knowledge gaps directly with sports nutritionists to contribute the design and development of a novel digital intervention. A similar successful approach was carried out by Ravalier *et al.* (2020) in the context of designing and developing a mental health and wellbeing app for use by UK social workers.

Study 1 identified the widespread use of social media as a digital extension of service provision in applied sports nutrition practice. Its inclusion was perceived as beneficial by sports nutrition practitioners who reported using multiple platforms to facilitate mobile and visual learning, as well as educate, nudge, and communicate with athletes across various environments, contexts and times of day. This bottom-up movement that has appeared in practice highlights sports nutritionists attempts to modernise their service delivery channels to keep up to date with the global shift towards digital communication that smartphones and mobile apps have introduced and the resulting shift in individual's information seeking behaviours in society (Newman *et al.,* 2017). However, the use of multiple platforms by sports nutritionists to share varied types of content and their identified inability to quantify the effectiveness of the digital support provided suggests a “spray and pray” or “hit and miss” approach was been employed (Govender & Parumasur, 2012). Similar practices have been previously identified and discussed in business literature where failures in implementing change occurred as a result of organisational leaders intervening prematurely and adopting this “spray and pray” or “hit and miss” approach to solve perceived organisational problems without a proper or planned diagnosis of the problem (Harrison & Shirom, 1999; Di Pofi, 2002). Sports nutritionists use of social media in this same way could also be described as product “hacking”, a modern concept that is characterised by the user of the product innovating on, modifying or redefining how the product is used (Bagli & Serifoglu, 2021). The concept of product hacking mainly belongs to the digital sphere where easy to access and affordable tools, as well as the emergence of new sharing mechanisms, are typically the target for hacking solutions to facilitate the implementation of new strategies and tactics (Certeau, 1984; Kuznetsov & Paulos, 2010). Wolf and McQuitty (2011) suggest that the motivation for engaging in these hacking behaviours may originate from external factors such as limitations in currently existing products to fulfill specific user needs. Given this, it is logical to infer that sports nutritionist’s social media behaviours suggest that they have been hacking these digital platforms in the absence of an industry specific tool to help them deliver digital support to athletes and capitalise on the benefits that scalable technology and mobile learning can bring to their practice. Pedagogy has a similar history but has progressed to industry specific tools where they can now demonstrate the resulting improvements in satisfaction, collaboration and success (Abuhassna *et al.*, 2020).

The findings of Study 1 also highlighted that absence of digital intervention and behaviour change expertise in sports nutritionists, as demonstrated by their current inability in how to measure digital intervention impact and their appetite for behaviour change training. The absenteeism of implementation science expertise could be a reflection of the maturity stage of the discipline. As outlined in chapter one, sports nutrition only established itself as its own discipline within the sports and exercise sciences in the 1980's and has created the majority of its evidence base since 2002. Given the youth of the discipline it may be no wonder that the integration of implementation science methods such as behavioural design and design thinking, as well as the development of theoretically driven DBCIs, have yet to permeate practice in sports nutrition. Instead, the disciplines research efforts to date have predominately focused on investigating nutrition's impact on metabolism, physiology and physical performance to develop the knowledge and evidence-base underpinning good practice as discussed in chapter two. However, as this underpinning evidence-base has become more established to effectively arm sports nutritionists with the most up to date knowledge and information, a practitioner's abilities to effectively translate this knowledge into athlete behaviours remains poor (Heaney *et al*, 2011; Heikura *et al.,* 2017; Bentley, Mitchell & Backhouse, 2020). Similar problems have been observed in healthcare settings (Martin *et al.,* 2015), however the inclusion of implementation science methods, such as utilising theoretical models of behaviour change to design interventions, have been shown to be effective in increasing patients' adherence to medication (Jackson *et al.,* 2014) and smoking cessation services (Fulton *et al.,* 2016). Evidence, again in healthcare settings, suggests that the combining behavioural interventions with digital delivery, i.e. DBCIs, can help change a range of health behaviours including alcohol consumption (Nair *et al.,* 2015), physical activity (Muntaner, Vidal-Conti & Palou, 2016) and self-management of chronic conditions (Jones, Lekhak & Kaewluang, 2014). Such technologies have also been lauded for their ability to save practitioner time (Tan *et al.,* 2023) and reduce organisation costs (Lou *et al.,* 2022). Given the above, Study 1 demonstrated sports nutritionists need for an industry specific mobile app DBCI whilst also highlighting important considerations for the design of such a technology from the practitioner's perspective.

The aim of Study 2 was to explore athletes' experiences and opinions of these communication strategies in applied sports nutrition, as well as capture their suggestions for future mobile app supportive solutions. A qualitative approach was used to acquire this understanding of what athletes think about the support they receive, as well as what they want from an industry specific technology. As outlined in chapter two, the human-centred design process seeks to understand the user of a product or service within context. As a result, this study sought to develop a knowledge base centred around understanding athletes' experiences and opinions of current practice so as to help establish potential problems and opportunities relevant to the design and development of a mobile app DBCI. Similar methods have been employed in the creation of modern medical products and services to improve the efficiency of implementation (Laurisz *et al.,* 2023). Additionally, integrating patients during every step of the develop process has been shown to make vital contributions to health technology assessments (Wale *et al.,* 2021). A similar successful approach was carried out by McClelland and Fitzgerald (2018) in the context of developing a mental health mobile app for service users and clinicians.

Study 2 demonstrated some of the knock-on effects of issues previously highlighted from practitioners in Study 1. Specifically, lack of time was identified as a challenge by sports nutritionists which athletes confirmed that they had experienced, and as a result also suffered from. Generic support and a distinct lack of personalisation were identified as problems for athletes who perceived their individual nutrition needs should be personalised and periodised to their own unique requirements. This desire for periodised nutrition demonstrates the rapid uptake and perceived usefulness of this practice by athletes since the "Fuel for the Work Required" paradigm was introduced by Impey and colleagues (2018). It could be that the more simple to comprehend and visual "low', "medium" and "high" colours proposed by this practice distilled what is quite a complex and nuanced topic into something that is easier to grasp for athletes (Bobek & Tversky, 2016). Athletes request for more personalised nutrition support though is not unique. As discussed in chapter two, sport nutritionists themselves have already been calling for this (Thomas, Erdman & Burke, 2016), however given the data captured on athletes in this thesis it appears that the discipline has yet to find an effective solution to action this call. This is contrast to other clinical fields of practice, such as medicine and healthcare, whose innovation efforts have enabled their entry into the personalisation and precision era as they move past population averages and group level approaches to health diagnostics and treatments towards ones that are individualised, contextualised and timely (Mathur & Sutton, 2017). These precision initiatives have demonstrated rapid, efficient and cost-effective learning that directly benefits the patients who provide the data and prevents potential fallacies of unfounded group to individual generalisability (Chevance, Perski & Hekler, 2020). A recent report by McKinsey (2021) also demonstrated that, in the general population, the global demand for personalisation is multiplying to the extent that in retail 71% of consumers now expect it and 76% of consumers get frustrated when personalisation is not delivered. In light of the above it appears that athletes' requests reflect a more general shift in society and sports nutrition should consider following in the footsteps of medicine and healthcare to transition into the personalisation and precision era. These findings identified important feature suggestions and athlete considerations that could be taken forward into Study 3 to aid the design and development of an innovative industry specific mobile app DBCI.

The aim of Study 3 was to act on the findings and recommendations of the previous two studies to design, develop and pilot a personalised sports nutrition DBCI for athletes. After identifying the shortfalls of previous sports nutrition interventions in chapter two, it was an objective of this study to ground the developed tool in a behaviour change theory, specifically the COM-B model and BCW, and clearly document the functional components of the intervention (Michie *et al.,* 2009). Given the complimentary nature of design thinking to the underpinning theory in developing more effectively engaging DBCIs (Short *et al.,* 2015; Perski *et al.,* 2016; Yardley *et al.,* 2016), both best practices were amalgamated, and a Behavioural Design Thinking approach was used of which the benefits have been described in chapter two. To capitalise on the previously discussed opportunities that digital technology could provide sports nutrition, another objective was to, using these approaches, ideate and design features that would solve problems and create value for both the sports nutritionist and athlete that could be delivered and interacted with across contexts, environments and at any time of the day. This approach is in contrast to previous sports nutrition interventions which as more "static" in nature and have predominantly relied on face-to-face consultations and group presentations (Bentley, Mitchell & Backhouse, 2020). The application of design thinking to sports nutrition is in of itself novel and, to the researcher's knowledge, this thesis is the first body of work within all of the sports and exercise sciences to draw upon the more robust Behavioural Design Thinking approach to intervention development.

As a result of engaging in this comprehensive design and development process, detailed throughout chapter five, a multi-feature sports nutrition specific mobile app DBCI was created. The removal of restrictions, specifically reliance on the sports nutritionist for personalised and periodised nutrition planning, is a unique to this DBCI and empowers athletes with a more autonomy supportive solution whilst also protecting sports nutritionist's time. This shift is also reflected in the use of the intervention function enablement and is evidenced in **Table 9**. This is a similar approach to healthcare settings where the adoption of autonomy supportive solutions has been shown to improve patient adherence (Delamter *et al.*, 2006). In education, an autonomy supportive teacher model is promoted (Oates, 2019) and satisfying this basic phycological need has also been shown to improve student motivation (Sierens *et al.,* 2009; Richardson, Karabenick & Watt, 2014). Research by Smit *et al.* (2019) has highlighted the importance of catering for factors such as autonomy and recommends a movement beyond only focusing on *what* information is provided during interventions, towards *how* it is provided. However, previous nutrition interventions within sport to date have tended to be more practitioner led using traditional education methods such as classroom seminars (Abood, Black & Birnbaum, 2014). Additionally, the autonomy supportive technology developed in Study 3 also responded to the desires of athletes, as well as the calls from Thomas, Erdman and Burke (2016) and Jonvik *et al.* (2022) in the literature base, by delivering a solution that provides personalised and periodised nutrition support. This advancement in delivering scalable and continuous personalised support could be considered an important early step in sports nutrition's transition into the personalisation and precision era discussed previously in this chapter.

Although the primary focus of Study 3 was centred around the creative journey and theory driven development of the industry specific mobile app DBCI, effectively documenting the process of going from "zero to one" (Thiel & Masters, 2014), the study did also capture some initial pilot data. This pilot data did provide some early insights into the potential of the technology and initial adoption by athletes as a resource to support their previously described needs. As discussed in chapter five, the initial engagement with the mobile app DBCI was high in comparison to other mHealth apps. However, the data also highlights distinct inter-individual differences between athletes, as well as intra-individual differences within athlete's usage of the platform and their planning behaviours. For example, some athletes displayed daily engagement and successfully created personalised plans for the majority of the pilot period, whereas other individuals did not engage with the DBCI or plan past day one. In addition, individual athlete data demonstrated that their own engagement varied significantly day-to-day. Chevance, Perski and Hekler (2020) suggest that this intra-individuality is typical of repeat-occurrence behaviours as they tend to be dynamic, multi-factorial and idiosyncratic. This is in agreement with Bauman *et al.* (2012) who demonstrated that health behaviours can vary day-to-day in response to changes in motivation. Similarly, research by Szinay and colleagues (2021) also highlighted the impact of inter-individual variations in motivation and its impact on health and wellbeing app uptake. Given this, and the importance of an appropriate performance focus and action plan for athlete behaviours described in chapter two, it could be hypothesised that the increased use of the mobile app DBCI observed on days that athletes had a training session may be a result of increases in athlete's motivation. Such dynamic variations in phycological state, as well as individual profiles, have been suggested to be import tailoring variables to optimise intervention engagement and effectiveness (Wang & Miller, 2019). In addition to future trials capturing longitudinal data to better determine mobile app DBCI longer-term behaviours and efficacy, combining this with phycological state and trait data may provide further context and opportunities for more precise tailoring interventions.

6.2 Conclusion

To conclude the research, this section brings together the core findings of each of the individual studies that make up the body of this thesis, as well as their contributions to achieving the final outcome of this body of work.

Sports nutrition's most aggressive period of growth and development to date has coincided the emergence and global adoption of novel mobile app technologies. Calls to explore and capitalise on the novel opportunities technology now affords the discipline, as well as the current lack of and need for more theory driven behavioural interventions, provided the rationale for this thesis. Study 1 clearly demonstrated the widespread use of social media by sports nutritionists as they embraced the use of digital platforms as an extension of their service provision to athletes. In addition to revealing this bottom-up movement, the varied use of platforms and "spay-and-pray" approach employed highlighted the opportunity for an industry specific platform that can deliver a more systematic approach to digital intervention delivery, whilst also identifying the current problems such as time and training that practitioners face. Study 2 verified athletes' acceptance and adoption of receiving sports nutrition support via mobile apps. The opinions captured established athletes clear desire for mobile technology solutions that can provide tailored nutrition support and cater for the perceived lack of personalisation and limited contact time they reported experiencing. Study 3 brought to life the findings of both Study 1 and Study 2 by leveraging both behavioural design and design thinking methods to design, develop and pilot a theory driven and autonomy supportive mobile app DBCI. In doing so, Study 3 embodied the core of the innovation methods used in this thesis through problem solving and creativity to deliver a digital innovation that initial pilot data demonstrates is practical, has a positive cost-benefit ratio, and provides an advantage for both athletes and sports nutritionists when compared with current digital practices.

6.3 Strengths of the Research

An overarching strength of this thesis was the mixed-methods approach used throughout. The use of both quantitative and qualitative methods during Study 1 facilitated the identification of the prevalence, perceptions and opinions, as well as new knowledge, in relation to the use of social media platforms as a digital extension of applied service provision in sports nutrition. No previous research has sought to capture the digital practices and experiences of applied sports nutrition practitioners to address the knowledge gap that has recently emerged as a result of the ubiquitous global uptake of technology. Qualitative methods embodied Study 2 and its use was the first to identify athletes own personal suggestions for future technology solutions, as well as establish their thoughts about the current level of service provision they receive. Tapping into the intellectual capital of athletes from a variety of sports and genders supported the development of innovative ideas and provided practical suggestions for improvements, as well as detected current perceived faults in the nutrition support they receive. No previous research had focused on gathering suggestions directly from athletes to aid the development of novel digital solutions to support practice. The combination of these new knowledge bases subsequently helped inform the direction, design and development of the research as it progressed.

The adoption of a Behavioural Design Thinking approach to the design of a digital intervention within the sport and exercise science disciplines is unique. There has been a recent call within the sports nutrition literature base for more theoretically driven behaviour change interventions (Bentley, Mitchell & Backhouse, 2020). The documentation of the underpinning theory, intervention functions and BCTs used in this thesis help to address these deficits in the current evidence base, whilst also helping to inform the design of future sports nutrition interventions, in particular those that integrate a digital element. Additionally, to the authors knowledge, this thesis is the first body of work to incorporate design thinking methods into sports nutrition research. Its application and success is well documented across other sectors such as clinical healthcare (Roberts *et al.,* 2016), as well as during new product development processes (Luchs, Swan & Griffin, 2015), and provided a rationale for its use in this body of work. The combined application of both behavioural design and design thinking has only recently emerged as best practice (Voorheis *et al.,* 2022), placing this body of work at the forefront of this movement.

Similarly, the innovation research approach employed in this thesis fostered creativity and multidisciplinary collaboration that facilitated divergent thinking within this body of work. By focusing on developing a knowledge base prior to deciding the direction of the innovation the research was able to respond to the nuanced findings and develop in a path that considered both the athlete and the sports nutritionist. The collaborative efforts between sports nutrition, behaviour change, design and technology is in of itself novel and up until this point absent from the sports nutrition literature. The unique viewpoints of each discipline supported the generation of unique ideas and insights throughout this thesis, whilst also answering calls from the sports nutrition field for improvements in personalisation (Thomas, Erdman & Burke, 2016), as well as the introduction of novel technologies (Jonvik *et al.,* 2022).

The overriding strength of this body of work, however, is the real-world applied impact it has had, as well as the potential it brings, to the sports nutrition discipline. Since the pilot of the mobile app DBCI, more than 750 athletes and in excess of 50 sports nutrition practitioners from a variety of sports and organisations have begun using the technology. The outcomes of this thesis are now discussed within major sporting leagues, such as the NBA, NFL and MLB, with regards expanding and improving the sports nutrition services available and practices employed. Similar conversations are also being had with national governing bodies, such as the Australian Institute of Sport, and other professional and Olympic sporting bodies. This is a key development and highlights the yield of scientific knowledge that has been directly translated to practice helping both athletes and sports nutritionists accomplish specific tasks and solve problems.

6.4 Limitations of the Research

The overarching challenge and limitation of this research was related to data collection from both existing digital technology platforms, as well as in applied sport settings. Capturing the direct content and messages being generated and delivered by sports nutrition practitioners, as well as their engagement with the various social media platforms during Study 1 was not possible due to data sharing restrictions of the social media platforms. Instead, professional social media usage was self-reported rather than captured in real time via each platform. As a result, deliberate misreporting and/or error cannot be ruled out. Additionally, the practitioners recruited for Study 1 were all based in the UK and Ireland and may not be representative of the worldwide sports nutrition community. This limitation was also present across Study's 2 and 3 where the athletes included in the research were based in either the UK or Ireland and their views and opinions may not be representative of the worldwide athlete community. Within Study 2 further insight could have been gained by collecting additional practitioner data to cross reference the athlete data with, however the findings were strictly describing this topic from an athlete's perspective which some practitioners may wish to contest.

There are several limitations that should be taken into consideration when interpreting the findings of Study 3. Given it was an initial pilot trial, the sample size was relatively small, and it was the only of the three studies with all male participants. This limits the generalisability of the findings. Specific areas of usability improvements were identified during prototyping but were not able to be implemented and therefore piloted due to financial resource constraints during the project. It can therefore not be ruled out that the inclusion of a feature such as notifications could have impacted the planning behaviours and engagement metrics during the pilot phase. This pilot testing period itself was also limited in duration and cannot, with certainty, be determined as indicative of longer-term behaviours and efficacy. Instead, the present thesis evidences a transparent and systematic approach to the development of a theoretically driven sports nutrition DBCI and provides an initial proof of concept that athletes can, when enabled by a novel technology, create personalised and periodised nutrition plans bespoke to their own training and competition demands in the short-term.

6.5 Recommendations

Drawing upon the key findings of this research, whilst also taking into consideration the strengths and weaknesses discussed above, the author offers suggested directions and recommendations for both future industry practice as well as academic research. These recommendations aim to contribute to the advancement of knowledge creation specific to technology and innovation within applied sports nutrition practice, as well as propose direct interventions for academics to explore.

Applied Recommendations

The initial recommendation is relevant to both the applied and academic communities, that is to embrace collaboration and avoid siloes. The integration of new technologies in elite sporting populations will rely on closer collaborations between researchers, practitioners, athletes and the technology companies themselves. As a result, we also recommend that practitioners continue to engage and become key stakeholders in this process and the future co-creation of novel technologies that are designed to be employed within the sports nutrition discipline. The second recommendation, built upon the foundations of this thesis, is to integrate behavioural design and design thinking processes into applied sports nutrition practice. Despite not being traditional sports nutrition "modules" there is a clear benefit to their use in problem solving and generating creative ideas both of which are important skills in applied settings. The final applied recommendation is to become an early adopter of technology to support practice, whilst remaining agnostic about the technology itself. The pace of change in this area is so rapid that those that do not evolve with the latest resources available run the risk of becoming “laggards” and falling behind as the “hybrid-practitioner”, who combines both the skill sets of humans and computers continues to evolve.

Research Recommendations

For academia, further research is required to understand the longer-term trends in the effectiveness, usage and uptake of the developed mobile app DBCI on a wider scale and across both male and female populations. This will facilitate a more representative picture of the longer-term impact of the technology on the nutrition planning behaviours of athletes. Given the differences observed in engagement between training and non-training days it also appears wise to explore the potential reasons for these differences and any further seasonality that may appear to inform and optimise future mobile app DBCI improvements. The reliability and validity of the algorithms developed in the mobile app DBCI should also be investigated. The inclusion of new features, such as notifications, should also be explored to better understand their impact of on planning behaviours and app engagement (Alkhaldi *et al.,* 2016; MacPherson *et al.,* 2019; Oakley-Girven *et al.,* 2021). These explorations into notifications should also seek to develop and explore dynamic tailoring interventions that aggregate data from multiple sources, including wearable devices, and have the ability to deliver individualised, contextualised and timely support to athletes (Riley *et al.,* 2011; Chevance, Perski & Hekler, 2020). Additional research efforts focusing on ideating, developing and validating algorithms that can help streamline further sports nutrition practitioners’ tasks should also be explored in an attempt to find ways to support practitioners to scale their service delivery across large squad sizes in a time and cost-effective manner. During these processes it is recommended that that the acceptability of any novel applications, as well as athletes’ engagement with these technologies, is explored (Perski *et al.,* 2016; Perski & Short, 2021). Finally, given the target behaviour of this mobile app DBCI was focused on planning, it seems a logical next step to now explore athletes' adherence to the plans, as well as strategies to optimise these associated behaviours.

6.6 Reflections on the Research Journey: There is only ahead and behind

For the final time, this section visits the philosophical location of the researcher before exploring the strengths, limitations and recommendations for both applied practice and future research.

Revisiting my position entering into this PhD, I was a deeply curios practitioner who had made observations in the field of applied practice that had reached a tipping point. At this point I had no research experience, no concept of the power of design and a limited understanding of innovation. My strengths were in applied practice and the art of conversation. My initial reflection at this present moment is centred around recognising how much has changed. I've transitioned from a practitioner who previously never would have considered academia, to now never wanting to leave it behind. That said I have a completely new appreciation for how difficult and disciplined academics need to be. Put simply, there is no short cuts. A proposition I quite like given there are clear strict processes to guide you on your journey. In many ways I think I enjoyed, what felt like to me at least, the linear process of carrying our research. What I mean by this is that every day of data collection or writing you are always one step closer to the goal, something that I probably don't get a lot of in my applied or entrepreneurial work which can be more rollercoaster like in terms of day-to-day experiences. Perhaps the millennial in me craves this acknowledgement of this demarcated progress from time to time, or maybe that's just what it feels like to be human. Either way, I feel acutely satisfied in progress made from Study 1 through to Study 3. That said, I do believe this thesis has now laid a foundation that previously didn't exist in sports nutrition for future work in this space.

As I’m sure many PhD students will attest to, the final few months of this process, the “write up” phase, has been challenging and has placed more of a strain on me than at any other stage of this PhD process. I suppose this feeling of being stretched is a by-product of juggling the time and mental capacity required to carry out this PhD, along with the pressures and immediacy of being a practitioner in elite sport, and the intensity and energy needed to deliver as an entrepreneur that now leads and manages a team. A lot of people would say my “plate is too full” or that I’ve “bitten off more than I can chew” but I actually find an unusual sense of calm and comfort in the absolute chaos. I really feel that this intersection of arenas is where I am meant to be. I recognise that this is an extremely privileged position I’m in and am grateful for each of the stresses that being a practitioner-researcher-entrepreneur brings me. I guess the thing I am most grateful for as a result of this is the diversity of conversations and expertise I’m now exposed to on a daily basis. The varied natured of these discussions, the different experts who I get to have them with, and the topics themselves, whether it’s a paper, a player or a product, all give me energy to keep pushing. Perhaps in some people’s eyes I’m now “too intense” but I think I actually just understand my role or my “why” in the world better. I am here to help people realise their potential. How I’ve done that in the past was being an applied sports nutrition practitioner who supported athletes on their individual and collective journeys. This research has now guided this energy towards not just athletes, but also the practitioners themselves, my people, where I am now on a journey to leverage advancements in technology to help unleash their potential to the world.

As a final reflection I would like to share a mindset towards the discipline of sports nutrition that I have often referred back to personally throughout this process. This mindset is derived from the work of Professor James Carse but more recently popularised by Simon Sinek in his book “The Infinite Game”. The concept is simple, in an infinite game, which I believe we are "playing" in sports nutrition, the players (practitioners and researchers) come and go, the rules (evidence base) changes, and there is no defined endpoint. In fact, unlike all of elite sport ironically, there are no winners or losers in an infinite game; there is only ahead and behind. I am committed to continuing pushing this area of our discipline forward and hope the atypical PhD path I took inspires more people to innovate and join me on this journey to keep moving the "game" forward together.

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Appendix 1: Example Interview and Focus Group Questions

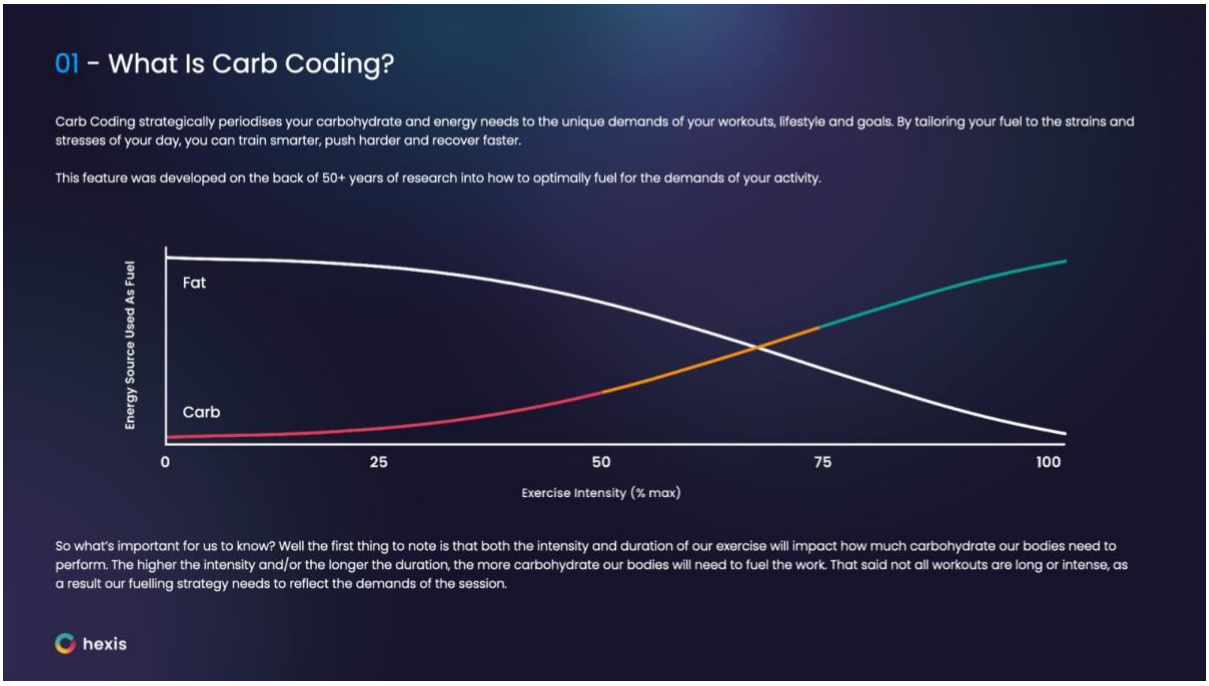
Study 1: Sports Nutritionist Interview Question Schedule

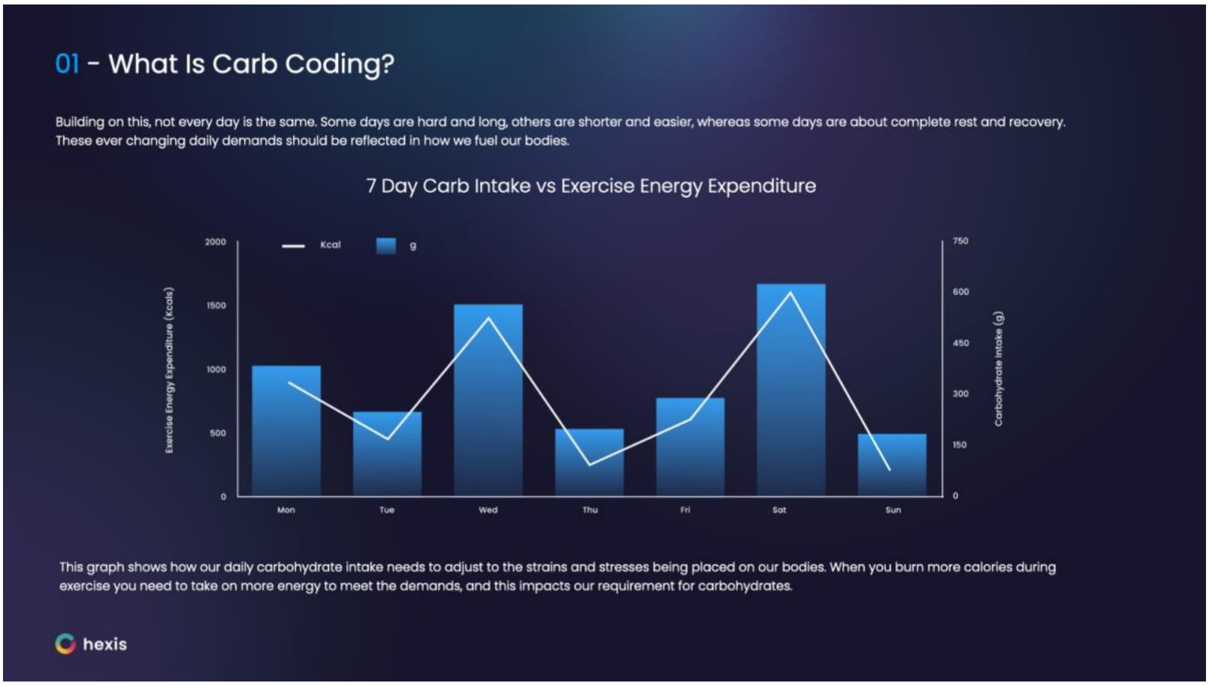
OBJECTIVES	KEY QUESTIONS
Establish sports nutritionists' experiences and opinions of social media use as part of service provision.	• Are you an active user of social media platforms? Why or why not? How do you use them? • Have you stopped using any social networks in the last year? If so why? • These sites have been around for a few years. Do you think their popularity is increasing or decreasing? Why? What platforms? • Have you used any of these social networks in your applied sports nutrition service provision sports? How? Please explain. • What platforms did you use? Why? • How effective or not did you find their use? • How did you feel about this method of information sharing? Do you have any concerns? Please explain. • Do you ever take precautions regarding private information? If so, what? • Have you ever used social networks for work purposes to share information about nutrition? Why? What platforms?
Establish sports nutritionist perspectives on digital training.	• Have you ever considered receiving formal training in this area? • Do you think this would be useful? Why?

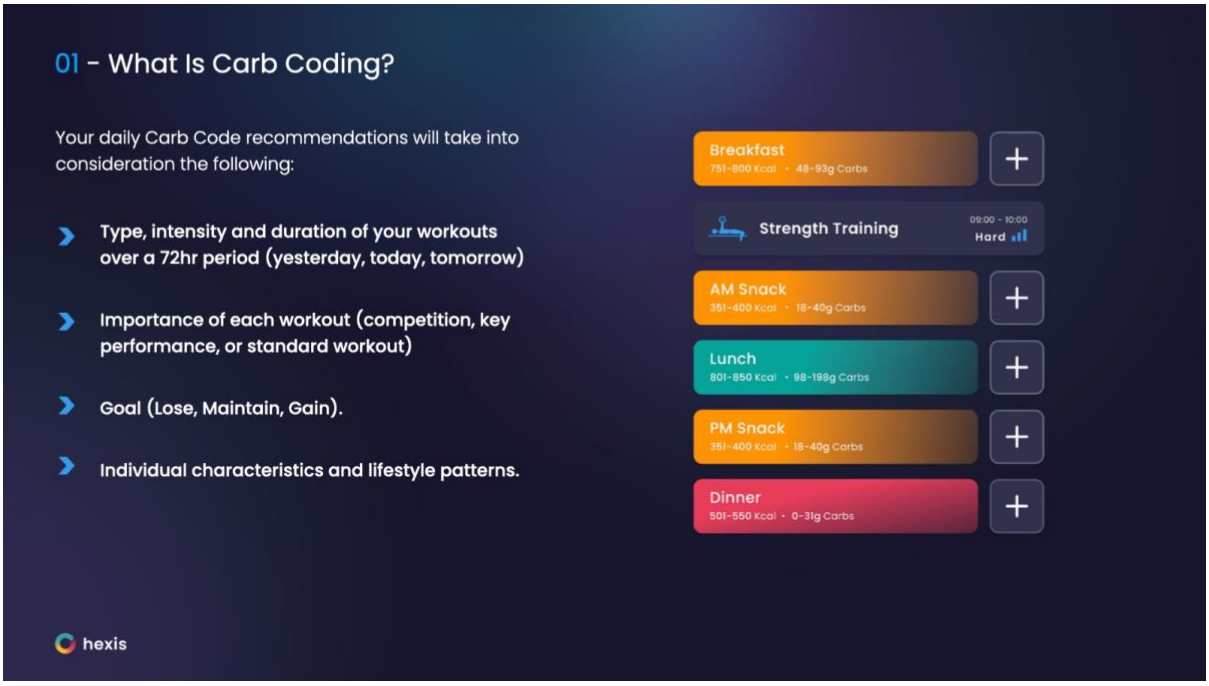
Study 2*:* Athlete Focus Group Question Schedule

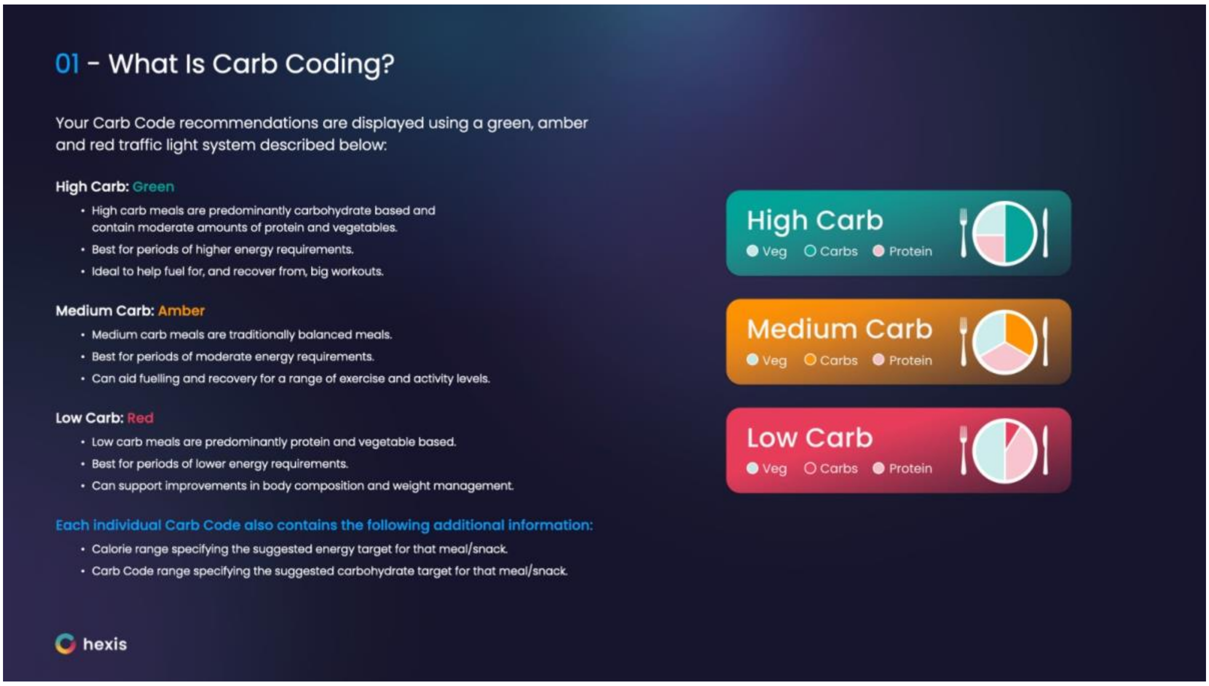
OBJECTIVES	KEY QUESTIONS
Obtain athletes' opinions of contemporary communication strategies in applied sports nutrition.	• Can you describe the current sports nutrition support you receive, if any, in terms of how it is delivered (for example format, frequency, contact time)? • What do you think of the current sports nutrition support provided to you in terms of how it is delivered? Can you describe your level of satisfaction or dissatisfaction? Why? • What do you think of the current support provided to you in terms of resources and how they are delivered? Can you describe your level of satisfaction? From your perspective how might the information be improved? • How would you describe the level of mental challenge you experience with respect to the resources and information that is delivered to you? Please explain. • How would you describe the level of physical challenge, such as cooking and shopping, you experience with respect to the resources and information that is delivered to you?
Establish potential problems and opportunities relevant to the development of a DBCI.	• Have you received any support via a mobile phone? If so, can you describe that? If not, is this something that you feel may be beneficial or not? • Are you aware of any personalised mobile apps that deliver sports nutrition support? Can you describe your experience of interacting with these? • What is your opinion of personalised mobile apps to help deliver sports nutrition support to you? How could this help or hinder your nutrition behaviours? Why or why not? • Do you think having this option could benefit you? Why or why not? In what situations specifically? • What are your thoughts on remote 1-2-1's? Would you take part? Why or why not?
Identify athletes' suggestions for future mobile app supportive solutions.	• What would drive you to open a nutrition app? For example, emotions such as boredom. • How frequently do you experience this? • What would the most important features of this app be to you? • What features would you have to have? Why? • What types of content would you prefer, for example, video, picture, text? Why? • Should content be tailored to your level of knowledge? Please explain.

Appendix 2: Example Material from Personalised Sports Nutrition DBCI Welcome Pack






01 - What Is Carb Coding?
Your daily Carb Code recommendations will take into consideration the following:
Type, intensity and duration of your workouts over a 72hr period (yesterday, today, tomorrow)
Importance of each workout (competition, key performance, or standard workout)
Goal (Lose, Maintain, Gain).
Individual characteristics and lifestyle patterns.
Breakfast
751-800 Kcal • 48-93g Carbs
Strength Training
09:00 - 10:00
Hard
AM Snack
351-400 Kcal • 18-40g Carbs
Lunch
801-850 Kcal • 98-198g Carbs
PM Snack
351-400 Kcal • 18-40g Carbs
Dinner
501-550 Kcal • 0-31g Carbs
hexis


01 - What Is Carb Coding?
Your Carb Code recommendations are displayed using a green, amber and red traffic light system described below:
High Carb: Green
High carb meals are predominantly carbohydrate based and contain moderate amounts of protein and vegetables.
Best for periods of higher energy requirements.
Ideal to help fuel for, and recover from, big workouts.
Medium Carb: Amber
Medium carb meals are traditionally balanced meals.
Best for periods of moderate energy requirements.
Can aid fuelling and recovery for a range of exercise and activity levels.
Low Carb: Red
Low carb meals are predominantly protein and vegetable based.
Best for periods of lower energy requirements.
Can support improvements in body composition and weight management.
Each individual Carb Code also contains the following additional information:
Calorie range specifying the suggested energy target for that meal/snack.
Carb Code range specifying the suggested carbohydrate target for that meal/snack.
High Carb
Veg Carbs Protein
Medium Carb
Veg Carbs Protein
Low Carb
Veg Carbs Protein
hexis

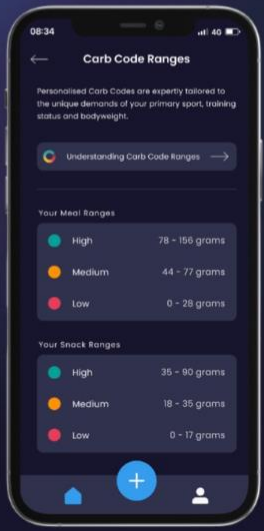
02 - Personalised Carb Code Ranges

Your Carb Code Ranges can be found in your profile and specify an approximate amount of carbohydrate you should consume in grams for a given meal or snack. These ranges are a guide and depending on the Carb Codes calorie target and workout scenario you may need to aim to consume the carbohydrates at either the lower or upper end of the range.

Your values are personalised to the unique demands of your primary sport, training status and bodyweight. You can adjust your Carb Code Ranges by altering the following in your profile:

- **Primary Sport**
- **Typical Exercise Hours Per Week**
- **Current Weight**

It is recommended you update these metrics as required to reflect any changes in your activity levels or physical profile.



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03 - How To Add Your Workouts

You can add up to 2 workouts per day to the Hexis platform.

To add a workout follow the below steps:

- Click the blue '+' icon in your navigation bar.
- Select the type of activity you plan on doing either from your favourites icons or the large '+' icon if you wish to select from the full list of sports and activities.
- Input your workout's planned **start and end time.**
- Select the intensity you plan on workout out at (light, moderate, hard).
- Select a **'workout slot'** by identifying when you will workout in relation to your planned meals and snacks before selecting **'Done'.**
- If relevant, you can identify if it is a **Competition** or **Key Performance Workout** using the toggles. Otherwise, at this point you can **'Save'** the workout.

Providing information that is as accurate as possible, in particular with regards to the workout type, intensity and duration enhances the accuracy of your data and supports optimal platform performance.

hexis

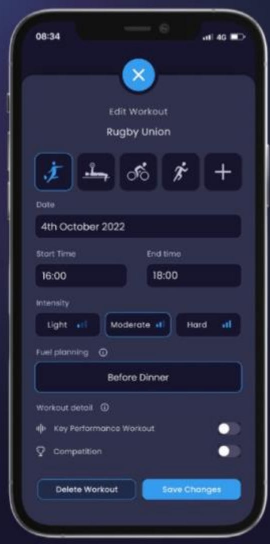
04 - How To Edit Your Workouts

To edit a workout follow the below step:

- Firstly, select the workout you wish to amend by tapping on it from your **Carb Code page.**
- At this point you should now see the planned workouts for that day and can **tap the workout you wish to amend.**
- Edit the workout as required before selecting **'Save'.**

To delete a workout follow the below step:

- Firstly, select the workout you wish to amend by tapping on it from your **Carb Code page.**
- If the workout you wish to amend is on another date, then select **'Today'** at the top of the page and navigate to the date of the workout before selecting **'View Day'**.
- At this point you should now see the planned workouts for that day and can **tap the workout you wish to delete.**
- Scroll to the bottom of the Workout page and select **'Delete Workout'.**



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05 -Tailored Kcals & Macros

Kcals & Macros provides you with your daily calorie, carbohydrate, protein and fat recommendations. You can discover more information about the role of each macronutrient you can tap on its card to see more details on its reverse.

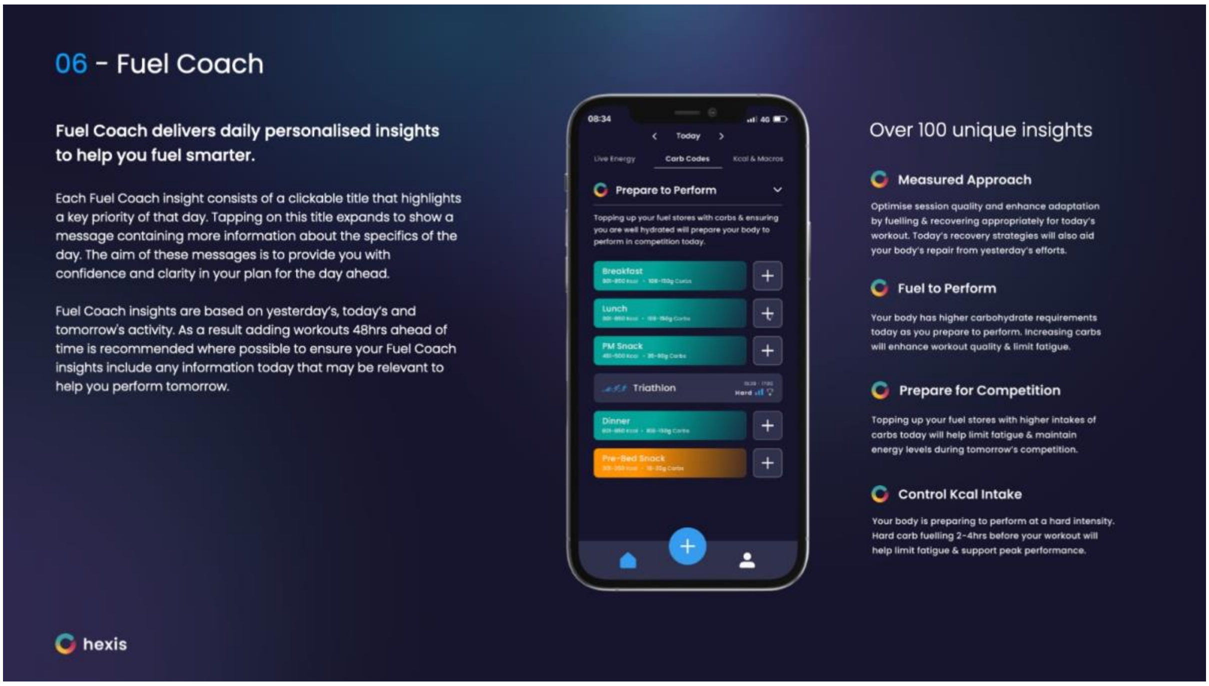
Your Kcal & Macro personalised values will vary day to day depending on the following:

- Workout type, intensity and duration.
- Competition and key performance workout schedule.
- Goal (Lose, Maintain, Gain).
- Individual characteristics and lifestyle patterns.

It is important to note that Kcals & Macros will also take into consideration yesterday's, today's and tomorrow's activity. As a result, adding workouts 48hrs ahead of time is recommended where possible to ensure your calorie and macronutrient targets are optimised to help you perform, adapt and recover each day.

hexis

05 - Tailored Kcals & Macros
The below image illustrates the day to day variations in an athletes energy and macronutrient requirements.
7 Day Kcal & Macronutrient Overview
Kcal
4000
3000
2000
1000
0
Mon 3,404 kcal 446g 171g 104g
Tue 2,650 kcal 261 163g 106g
Wed 2,945 kcal 323 168g 109g
Thu 2,287 kcal 202g 156g 95g
Fri 3,542 kcal 484g 172g 102g
Sat 3,827 kcal 562g 172g 99g
Sun 2,768 kcal 265g 175g 112g
Fat
Protein
Carbohydrate
hexis



06 - Fuel Coach
Fuel Coach delivers daily personalised insights to help you fuel smarter.
Each Fuel Coach insight consists of a clickable title that highlights a key priority of that day. Tapping on this title expands to show a message containing more information about the specifics of the day. The aim of these messages is to provide you with confidence and clarity in your plan for the day ahead.
Fuel Coach insights are based on yesterday's, today's and tomorrow's activity. As a result adding workouts 48hrs ahead of time is recommended where possible to ensure your Fuel Coach insights include any information today that may be relevant to help you perform tomorrow.
08:34
Today
Live Energy
Carb Codes
Kcal & Macros
Prepare to Perform
Topping up your fuel stores with carbs & ensuring you are well hydrated will prepare your body to perform in competition today.
Breakfast
Lunch
PM Snack
Triathlon
Hard
Dinner
Pre-Bed Snack
Over 100 unique insights
Measured Approach
Optimise session quality and enhance adaptation by fuelling & recovering appropriately for today's workout. Today's recovery strategies will also aid your body's repair from yesterday's efforts.
Fuel to Perform
Your body has higher carbohydrate requirements today as you prepare to perform. Increasing carbs will enhance workout quality & limit fatigue.
Prepare for Competition
Topping up your fuel stores with higher intakes of carbs today will help limit fatigue & maintain energy levels during tomorrow's competition.
Control Kcal Intake
Your body is preparing to perform at a hard intensity. Hard carb fuelling 2-4hrs before your workout will help limit fatigue & support peak performance.
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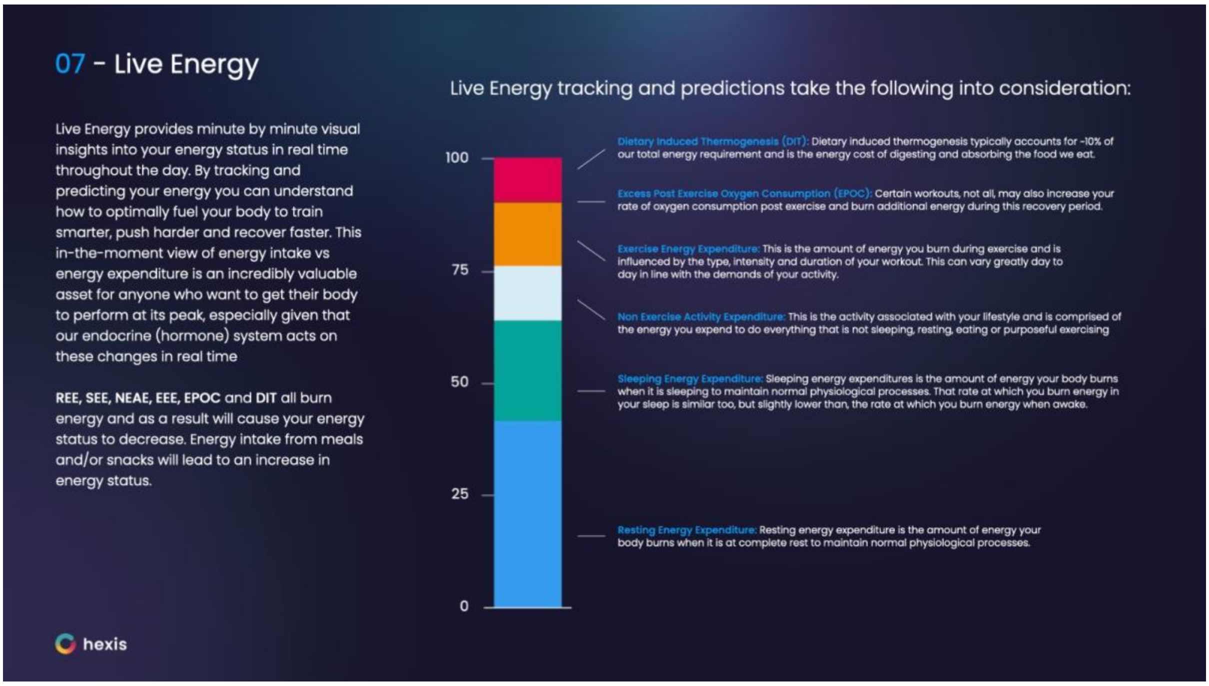
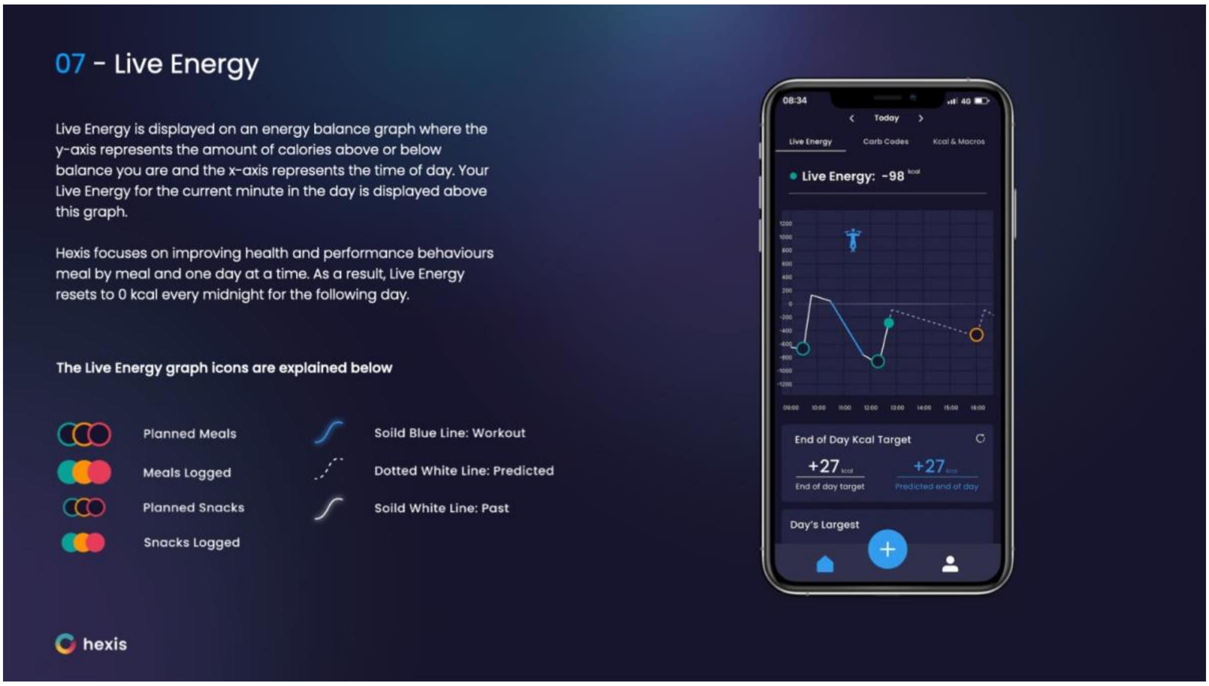

07 - Live Energy
Live Energy provides minute by minute visual insights into your energy status in real time throughout the day. By tracking and predicting your energy you can understand how to optimally fuel your body to train smarter, push harder and recover faster. This in-the-moment view of energy intake vs energy expenditure is an incredibly valuable asset for anyone who want to get their body to perform at its peak, especially given that our endocrine (hormone) system acts on these changes in real time
REE, SEE, NEAE, EEE, EPOC and DIT all burn energy and as a result will cause your energy status to decrease. Energy intake from meals and/or snacks will lead to an increase in energy status.
Live Energy tracking and predictions take the following into consideration:
100
75
50
25
0
Dietary Induced Thermogenesis (DIT): Dietary induced thermogenesis typically accounts for ~10% of our total energy requirement and is the energy cost of digesting and absorbing the food we eat.
Excess Post Exercise Oxygen Consumption (EPOC): Certain workouts, not all, may also increase your rate of oxygen consumption post exercise and burn additional energy during this recovery period.
Exercise Energy Expenditure: This is the amount of energy you burn during exercise and is influenced by the type, intensity and duration of your workout. This can vary greatly day to day in line with the demands of your activity.
Non Exercise Activity Expenditure: This is the activity associated with your lifestyle and is comprised of the energy you expend to do everything that is not sleeping, resting, eating or purposeful exercising
Sleeping Energy Expenditure: Sleeping energy expenditures is the amount of energy your body burns when it is sleeping to maintain normal physiological processes. That rate at which you burn energy in your sleep is similar too, but slightly lower than, the rate at which you burn energy when awake.
Resting Energy Expenditure: Resting energy expenditure is the amount of energy your body burns when it is at complete rest to maintain normal physiological processes.
hexis


07 - Live Energy
Live Energy is displayed on an energy balance graph where the y-axis represents the amount of calories above or below balance you are and the x-axis represents the time of day. Your Live Energy for the current minute in the day is displayed above this graph.
Hexis focuses on improving health and performance behaviours meal by meal and one day at a time. As a result, Live Energy resets to 0 kcal every midnight for the following day.
The Live Energy graph icons are explained below
Planned Meals
Meals Logged
Planned Snacks
Snacks Logged
Solid Blue Line: Workout
Dotted White Line: Predicted
Solid White Line: Past
08:34
Today
Live Energy
Carb Codes
Kcal & Macros
Live Energy: -98
End of Day Kcal Target
+27
End of day target
+27
Predicted end of day
Day's Largest
hexis