UNDERSTANDING PHYSICAL PERFORMANCE DATA: AN INVESTIGATION INTO THE USE OF INFORMATION IN THE SUPPORT OF PLAYER DEVELOPMENT IN ELITE ACADEMY SOCCER

by

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Abstract

Soccer is becoming an ever more physically challenging sport, demanding athletes to possess a myriad of high-level physical capacities. Performance practitioners, providing physical support to soccer players, utilise technology and monitoring systems to gather data on their players physical status, and support decision making. Whilst research has begun to explore the use of collected data, thus far, none has examined the holistic approach to monitoring and the potential impact physical performance data can have on club-based decision making.

The initial phase of the project aimed to present a multi-club investigation to detail current physical performance monitoring practices, and opinions of elite soccer practitioners. Utilising an online survey, respondents highlighted the presence of a multitude of technologies, monitoring areas, and manners of data analysis. Whilst practitioners noted an increase in the data collected, only a quarter of clubs operated with a specialist data practitioner. Furthermore, practitioners evidenced redundancy in data collected, along with complex systems of data processing. Positively, practitioners did feel their monitoring practices provided a return on investment and allowed them to achieve their aims. Whilst data is certainly supporting practice within soccer clubs, this study presented concerns regarding the efficacy of current monitoring practices.

The second phase of the project increased focus on physical performance data processes. By combining observational analysis with interviews, the study aimed to determine the processes of physical performance data monitoring within an ‘example’ club. A wealth of data was collected across wellbeing, pitch-based loading, gym-based performance, and physical capacity testing. Despite evidence of data use to support the

player development process, inefficiencies were again identified. Despite regular data feedback, coaching staff did not fully engage with the data. They were also shown to place reliance on their performance staff to feedback key insights. It was suggested this may be through a lack of understanding, or lack of interest in the data. It also confirmed the importance of effective and trusting relationships between performance and coaching staff.

The third phase aimed to enhance the efficacy and efficiency of physical performance monitoring through a modified feedback strategy. The first study of phase three aimed to extract insightful metrics that would be used in the feedback strategy. Results highlighted the importance of understanding the associations between changes in performance, and the complexity of physical development. Nonetheless, data highlighted the potential that manipulation of training demand to increase players' exposure to distance covered, and internal demand, may promote a more challenging physiological stimulus, that could result in positive fitness adaptations.

This finding was used to inform the intervention process in the modification of club-based feedback strategies within the second study of phase three. The intervention successfully impacted change within the club. Through increasing coaches awareness and understanding of data, whilst reducing the amount of data presented to them in reports, training demand increased. During post-intervention interviews with coaching staff, it was clear that the positive impact of the intervention was due to this combined approach.

This research highlights the importance of ensuring collected data is accurate, informative and effectively translated to stakeholders. Through education of the importance and impact of data, physical performance information can have an impact upon the player development process within soccer clubs.

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Contents

Abbreviations

Matchdays, MD (in-text example: MD+1 = One day after the match day)

Maximal oxygen uptake, VO2

Heart rate, HR

Acute chronic work ratio, ACWR

Global Position Systems, GPS

Local Position Measurements, LPM

Rating of perceived exertion, RPE

Intermittent fitness test, IFT

Velocity-based training, VBT

Dual x-ray absorptiometry, DEXA

Athlete management system, AMS

Elite Player Performance Plan, EPPP

Club academy Scotland, CAS

Smallest worthwhile change, SWC

GK, Goalkeeper

Linear mixed modelling, LMM

Countermovement jump, CMJ

Intraclass correlation coefficient, ICC

Hertz, Hz

Total distance, TD

High intensity distance, HID

Sprint distance, SD

High intensity decelerations, HIDec

High intensity accelerations, HIAcc

Heart rate exertion, HREx

Coefficient of determination, R^2

Confidence Intervals, CI

Cohen's D, d

Hedges G, g

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1.1 Introduction

Success in professional soccer offers both the prestige of winning titles and lucrative monetary rewards for teams at the elite level (Menary, 2016; Deloitte, 2019; Georgievski, et al., 2019). In season 2019/2020, the total financial prize money for teams who qualified for the European Union of Football Association's (UEFA) premier competitions, the Champions League and Europa League, was a combined EUR 2.5 billion (UEFA, 2019). Positive results can therefore provide access to increased revenue streams, thereby creating positive feedback loops that allow further financial rewards to increase subsequent investment within a club. This cycle acts to sustain the ability of clubs to successfully compete in the relevant major competitions (Szymanski, 2001; Pawlowski, et al., 2010; Brink, et al., 2018; Madsen, et al., 2018). These opportunities impact procedures and practices that are aimed at identifying and implementing strategies that may create a competitive advantage and therefore the likelihood of achieving success.

There are many facets that influence success in soccer from a performance perspective. These include the technical, tactical, and psychological abilities of the individual players (Lago-Penas, et al., 2010; Lago-Penas, et al., 2011; Owen & Dellal, 2016). Another important factor is the physical capabilities of soccer players. Soccer is a physically challenging sport, placing demands on many physiological capacities. (Arnason, et al., 2004; Stølen, et al., 2005; Bloomfield, et al., 2007; Sporis, et al., 2009). These physical demands are made more complex with players competing within heavily congested fixture schedules, combined with extensive travel demands. Individuals may play two or even three matches within short time periods (e.g., seven days) in potentially different countries, for prolonged periods of the season (Gouttebarge, et al., 2019; Julian, et al., 2021). Therefore, clubs and their players are challenged to sustain high performance levels both within individual matches and across the duration of competitive participation, in their pursuit of success.

To support these needs, clubs employ specialist personnel to plan and implement strategies related to the physical performance of players. These specialist practitioners (e.g., sport scientists/physical performance coaches) are primarily drawn from academic backgrounds as the application of scientific knowledge and principals of human physiology and sport science are crucial in this process (Reilly & Gilbourne, 2003; Drust & Green, 2013). Physical performance strategies aim to develop the physical capacities of the players, monitoring players response to exercise and recovery, and attempting to mitigate injury risk (Sewell, et al., 2012; Drew, et al., 2017; Brink, et al., 2018).

To positively influence these areas, sport scientists frequently collect data from their players. This data can provide information on both the activity and the response of players to the physical challenge of training and match play. This information frequently relates to the external (what players do) and internal (how they respond) efforts of the players. These aspects represent important components of the relationship between exercise and the outcomes of this exercise for the individual (Wing, 2018). Many studies have examined the impact of such data from a research perspective and have indicated that inappropriate physical loading or insufficient recovery, as monitored using technology such as global positioning systems (GPS), can influence injury incidence (Gabbett, et al., 2014; Malone, et al., 2017; Jones, et al., 2017). This is important as low injury incidence levels and days lost to injury are related to positive performance outcomes over the course of a season (Arnason, et al., 2004; Eirale, et al., 2013; Hägglund, et al., 2013; Drew, et al., 2017). Additionally, better developed physical characteristics (e.g., aerobic fitness and anaerobic power) also appear beneficial to performance and success (Wisloff, et al., 1998; Ostojic, 2004; Helgerud, et al., 2011). Such physical developments can be achieved through exposure to an appropriate physical stimulus, which can again be assessed using technology and physical performance monitoring processes (Hoff, et al., 2002; Castagna, et al., 2011). Given these demands and requirements, the information collected from the monitoring processes is primarily used to support decision making within the club (Nosek, et al., 2021; Evans, et al., 2022). The data can be used in collaboration with other stakeholders, such as coaching staff, within the training session planning process (Reilly & Gilbourne, 2003; Drust & Green, 2013; Weston, 2018; Nosek, et al., 2021). Through these data informed decisions, it is perceived that the outcome is beneficial, thereby supporting the objectives of ensuring players remain available, and physical development can be achieved.

However, despite the advantages likely gained through the effective use of physical performance data in soccer, there appears to be a lack of research regarding the actual data processes associated with data use within applied environments. This extends to all aspects of activity related to the physical performance monitoring process, including collection, analysis, feedback, and use of data.

Before data can be used, it is first vital to ascertain the information deemed worthy of collecting. Due to the abundance of monitoring technology available, there are endless possibilities of combinations of data that can be collected. This adds to the complexity of establishing an efficient and effective data monitoring system. Whilst examining metrics involved in training load monitoring in soccer, over fifty different variables were cited as being used in some way (Akenhead & Nassis, 2016). This large number of possible physical metrics, many technological brand specific, likely suggests that some will lack "empirical support for their validity, reliability, and usefulness" (Akenhead & Nassis, 2016). This can negatively impact the monitoring process, with data potentially not providing a clear and reliable conclusion to support an actionable outcome.

Research has also highlighted a lack of appropriate application of statistical methods in the analysis of the data, suggesting limitations about the interpretation and the use of data (Akenhead & Nassis, 2016; Malone, et al., 2019). This appears to suggest that the processes around physical data use is currently driven by subjective judgments based on practitioner experience, as opposed to empirical evidence. There also appears to be a lack of appropriate software being used to process data (Asimakidis, et al., 2024). This could impact the efficiency and ability of practitioners to suitable analyse their data. Again, by not accurately analysing this information, decision making may be based upon ineffectual or erroneous data, thus impacting the ability of the data to effectively support positive change.

Yet, even if these initial stages are successful within a club, the effectiveness of the data can still be diminished through ineffective “translation of science” to key stakeholders within a club (Malone, et al., 2019). Areas that may be problematic include the excessive amounts of information that can be presented back to coaches and players, in addition to “poor communication” between performance practitioners and coaching staff (Nosek, et al., 2021). If there is a breakdown between the interpretation of important insights to actionable information, successful outcomes may not be forthcoming. Such inability to act effectively and/or support club strategies appropriately may be damaging to the outcomes of a soccer club (Drust, 2019).

Therefore, this thesis aims to examine the current use of physical performance monitoring within elite soccer, with a specific focus on how this data is incorporated into practice.

1.2 Aims and Objectives

The primary aim of this research is:

To describe, critically analyse, and influence the use of physical performance data in the support of physical development of elite youth soccer players.

This aim will be addressed through the completion of the following targeted objectives.

- Describe and evaluate the organisational structure, and the collection, processing, and use of physical performance data in professional soccer
- Understand the process and the rationale that drive data collection, processing, and use of physical performance data in an elite academy soccer club
- Explore the relationship between physical performance data and physical testing to evaluate the development of focused data feedback and use
- Assess and evaluate the potential for an evidence-informed data use strategy to influence changes in the planning of physical performance development

2.1 Literature Review – Introduction to Soccer

"Data is like garbage.

You had better know what you are going to do with it before you collect it"

- Mark Twain

Soccer, the "world's game" is played by an estimated 265 million people globally (Dvorak, et al., 2004; Kunz, 2015). With massive worldwide interest and investment in the sport, the financial commitments, and rewards available for teams, especially those competing in the top leagues, is significant (Menary, 2016; Deloitte, 2019; Georgievski, et al., 2019). Subsequently, soccer teams are investing in staffing and technology to uncover areas of potential development, where they could gain an advantage over their competitors (Drust & Green, 2013; Drust, 2019). Among these areas of development, are those that are required for successful performance; technical, tactical, psychological, and physical abilities (Arnason, et al., 2004; Lago-Penas, et al., 2010; Lago-Penas, et al., 2011; Bangsbo, 2015; Owen & Dellal, 2016; Hostrup & Bangsbo, 2022). Current research anticipates increases in the physical demands of soccer in the coming years. This is fuelled by the addition of more fixtures per season (FIFPRO, 2019; FIFPRO, 2023) and a potential for trends showing increases in match play intensity to continue (Barnes, et al., 2014; Nassis, et al., 2020; Harper, et al., 2021; Allen, et al., 2023). This is creating concern regarding the wellbeing and physical status of soccer players around the globe (FIFPRO, 2023). As such, there is clearly the requirement for effective methods to monitor soccer players' physical status, their capacity to cope with these physical rigors, and reduce the increased risk now imposed upon them by the setup of modern soccer. With advances in technology now allowing for the possibility of enhanced monitoring and insight, it is pertinent that research explores what is currently being done to incorporate this information into club-based practices.

The primary focus of this literature review concerns the physical component of performance, beginning with an examination of the specific physical and physiological demands of the game. This will investigate the physical demands placed upon players during match play, and across the season. Following this, training as a method to develop the physical capacities set out in the previous chapters will be discussed. This section will also look at the physical determinants of performance. This will be followed by the role of the performance practitioner, and the use of technology and monitoring processes to assist in the development of physical performance, and mitigation of risks to players. The review will end by exploring the processes required to support data monitoring, in addition to concerns raised in current literature regarding data monitoring. Together, this review should present the importance of physical attributes in soccer, explore the current implementation of physical performance data in soccer, and why the collection of data relating to physical performance is important in the support provided to soccer clubs.

2.2 Physical and Physiological Soccer Demands

Soccer is a physically demanding sport, involving multidirectional movement, at varied speeds, with the addition of technical interactions with a ball, and the likelihood of collisions with other players (Stølen, et al., 2005; Bangsbo, et al., 2006; Taylor, et al., 2017). The general rules of a soccer match are well established and set the guidance for the match constraints, resulting in pre-determined boundaries for duration, playing numbers, and dimensions. Senior regulation soccer matches last 90 minutes, played across two 45-minute halves, separated by a 15-minute half time interval. In certain competitions, an additional 30 minutes and a penalty shootout may be required to determine a winning side, should both sides be level on scoring by the end of normal time (The International Football Association Board, 2021).

The soccer match is viewed as the most physically demanding component of a soccer players' week (microcycle) (Anderson, et al., 2016; Kelly, et al., 2020). The physical actions and demands of a soccer match have been extensively quantified using several research methodologies. Initial studies quantifying physical match demands made use of video recordings and manual analysis (Reilly & Thomas, 1976). Through the development of technology such as computerised video analysis, and wearable systems, collection of physical data is now more efficient and precise (Carling, et al., 2008; Sarmento, et al., 2014; Dolci, et al., 2020). Research indicates elite professional soccer players cover a total distance of 9 to 14 km during a 90-minute match (Vigne, et al., 2010; Sarmento, et al., 2014). The breakdown of this total distance covered by outfield players shows around 5% of the match is spent standing, around 85% of the distance covered is at low intensity (walking or jogging: <14.4 km/h) and the remainder is covered at higher velocities, incorporating high intensity running and sprinting (Bradley, et al., 2009). These locomotive breakdowns have been substantiated through monitoring across many high-level leagues (Spanish Premier League, UEFA Champions League, and UEFA Europa League) (Di Salvo, et al., 2007; Andrejewski, et al., 2015).

Despite a clear understanding of the normative match physical outputs, research has also indicated that these demands vary based upon playing position (Bloomfield, et al., 2007; Di Salvo, et al., 2007; Ade, et al., 2016; Morgans, et al., 2022; Allen, et al., 2023). Midfield players have been shown to cover the highest total distance during a soccer match (Bradley, et al., 2010; Abbott, et al., 2018). Wide players run a greater distance at high-speed and sprint velocities, in addition to reaching higher maximal velocities, than central players (Bradley, et al., 2010; Abbott, et al., 2018).

These positional differences may also be influenced by the tactical setup of the squad, namely the formation. A formational setup of a 1-4-4-2 or 1-4-3-3 led to a greater distance covered at jogging speed, whereas the 1-4-5-1 setup led to a greater distance walking. However, this latter formation led to higher distances of high-speed running when the team is not in possession of the ball, compared to the former formations (Bradley, et al., 2011). Further research showed a change of style and formation (1-4-5-1 to 1-3-5-2) of an elite Norwegian soccer team, as a consequence of managerial change, led to the expected high-intensity running (>19.8 km/h) distances of wide players to increase, in addition to the number of high-intensity running actions of centre backs to decrease (Baptista, et al., 2019). This indicates that the physical demands for players can be altered within the same team, through a change in tactical setup, potentially stimulating a change in an individual's match physical outputs. This developed insight of the physical demands of soccer has now created a greater appreciation of the energy systems support of soccer performance.

Due to the intermittent nature and range of the physical demands required for the sport, the full spectrum of energy systems are utilised to appropriately meet the necessary requirements to sustain activity (Bangsbo, et al., 2006; Castellano, et al., 2011; Sarmento, et al., 2014; Dolci, et al., 2018). This energy demand spans "maximal efforts" to "endurance intensive efforts" encompassing the immediate anaerobic phosphocreatine system and anaerobic energy pathways, to the aerobic energy systems (Chamari & Padulo, 2015). With most of the physical actions being completed at low intensity, the aerobic energy pathway is the prevailing energy system for soccer players (Di Salvo, et al., 2007;

Bradley, et al., 2009; Andrejewski, et al., 2015). Soccer players with a developed aerobic capacity (e.g., >60 $ml.kg^{-1}.min^{-1}$) may benefit from the ability to complete physical activity for longer durations, more efficiently, and at a higher intensity than those with a less developed capacity (Helgerud, et al., 2001).

In addition to the aerobic profile of soccer players, their anaerobic capacity is also influential upon performance. Despite a low percentage of overall distance covered at high intensity, information extracted from soccer matches has highlighted the importance of a developed anaerobic capacity. It is within this activity zone that crucial match deciding moments such as goals can emanate. For example, sprinting has been shown to be the most common action for scoring and assisting players in a review of goals scored in the German Bundesliga (Faude, et al., 2012). Such a developed capacity may allow for the repeated performance of such game deciding actions. This is also beneficial when considering that the volume of running at high-intensity speeds has also been shown to be increasing within the soccer. This trend is potentially down to improved and targeted physical training and/or a superior level of athletes participating within the sport (Barnes, et al., 2014; Bush, et al., 2015; Hostrup & Bangsbo, 2022).

Due to the multidirectional nature of soccer, there is also need for players to perform turning and swerving actions to change direction, some of which will also be classified as high intensity. High intensity actions (including sprinting and jumping) occur around one every 60-90 seconds, lasting 2-3 seconds on average, in a soccer match (Stølen, et al., 2005; Haugen, et al., 2013; Filter, et al., 2023). Research by Ade, Fitzpatrick, and Bradley (2016) highlighted an immense non-linear demand in soccer, necessitating skills and physical qualities beyond straight line running. The authors investigated the movement patterns involved in high intensity actions, including turns and curved runs. They found that most high intensity actions were performed following or prior to a 0-90° turn. Notational analysis by Morgan et al (2022) highlighted players averaged 3.13 changes of direction per minute. When investigating the most common change of direction angle, they found the majority if turns to be ≤90°. Interestingly, significantly more changes of directions occurred within the opening 15-minutes of the match compared to the final 15-minutes, suggesting a possible impact of fatigue on the expression of high intensity actions. These high intensity actions necessitate players to produce forceful contractions, requiring rapid production of muscular force (Helgerud, et al., 2011). This ability to produce high levels of force at high speed translates into power, associated with sprinting, changes of direction, and the ability to dual with opponents (Hoff & Helgerud, 2004; Helgerud, et al., 2011). The high-intensity nature of these actions will likely prioritise the anaerobic and phosphocreatine energy systems, whilst the repeated nature of them across the match will draw on the aerobic system to allow for continuation of the actions. Therefore, development of energy systems is likely beneficial for the athletes to continue to produce high-intensity actions.

Research has examined the physiological response to the physical outputs seen in soccer matches, or laboratory imitations of soccer matches. They have shown increases in heart rate (HR) to around 85% of maximal values, increases in ventilation rate, and oxygen uptake, averaging around 70-75% of maximal values (VO_{2max}) (Bangsbo, et al., 2007). The utilisation of anaerobic energy pathways can also be seen through the physiological response of increases in blood lactate levels, a by-product of the anaerobic energy system (Bangsbo, 1994; Krustrup, et al., 2006). The recording of some measures exceeding 10mM of blood lactate highlight the stress placed upon the system during soccer. Despite these high intensity actions being predominantly short in duration, the involved eccentric component significantly contributes towards muscular damage. (Owen, et al., 2017; Hader, et al., 2019). This mechanical stress can be identified through increased levels of serum creatine kinase (CK), a key enzyme involved in the phosphocreatine energy system (Bangsbo, et al., 2007; Baird, et al., 2012). Additionally, this is a proxy marker of muscular cell damage, emphasising the physiological consequences of soccer.

The understanding of the physical and physiological demands placed upon soccer players highlights the complexity of soccer as a sport, and the myriad of factors that must be considered to support physical performance. However, these demands are amplified when considered in the context of a full-soccer season, necessitating the repetitive completion of these actions within training and match play.

2.3 Understanding Players' Physical Demands Across A Soccer Season

A standard season lasts around ten to eleven months, with a typical preparatory period (pre-season) of four to six weeks at the start, and rest period (off-season) of four to six weeks after the cessation of competitive fixtures (Malone, et al., 2015; Silva, et al., 2016). Dependant on performance of domestic and national squads, a player's season may be shortened or extended based upon progression within competitions (Reilly & Ekblom, 2005). Some competitions (e.g., FIFA World Cup) may be played during the off-season, reducing the time off elite players have per season, with some elite players having as little as three weeks off a year (Walker & Hawkins, 2018). This results in elite players potentially competing for both their domestic club and national team in as many as sixty to ninety fixtures per season (Carling, et al., 2012; Ekstrand, et al., 2016; FIFPRO, 2021). These games can be competed across numerous competitions and several countries. In addition to the fixture demands, soccer players also participate in around 220-240 training sessions per season (Ekstrand, et al., 2016).

Across the season, this creates a balancing act for soccer clubs, between the desire to work on developing their players in between quick match turnaround times, whilst ensuring players can properly recover. With reports highlighting the extreme strain placed upon players (FIFPRO, 2023), it is important both clubs and players have appropriate support in place. This is to ensure impactful and appropriate development can take place, whilst respecting the extreme demands of a soccer season.

2.4 Soccer Training and Periodisation

By understanding the range of physical demands of soccer across the soccer season, it is evident that specific training to target development of physical qualities is required. The general purpose of training is the enhancement of physical and sport-specific skills to improve performance levels (Viru & Viru, 2000; Impellizzeri, et al., 2019). As acknowledged by Impellizzeri, Marcora and Coutts (2019), “training needs to target the systems that determine performance”. From a physical perspective, this can be a general approach to prepare players for the high volume of work they are likely to experience, or more specifically, develop physical characteristics at an individual, or group level.

Whereas the physical demands of a soccer match have been extensively quantified (Carling, et al., 2008; Sarmento, et al., 2014; Dolci, et al., 2020), the physical and physiological demands of soccer training are harder to generalise due to the immense variability that can occur between sessions, the phases in season, and team philosophies (Anderson, et al., 2016). Both the physical outputs and the physiological demands constitute the physical load experienced by soccer players, categorised as external and internal loading respectively (Stevens, et al., 2017; Wing, 2018; Impellizzeri, et al., 2019; Teixeira, et al., 2021). The physical loading experienced by the players during training can be manipulated to provide the appropriate level of physical work (Impellizzeri, et al., 2005). When physical stimuli and their corresponding physiological response of appropriate magnitude are applied repeatedly, chronic physiological adaptations can occur, resulting in physiological development that may assist in developing performance (Impellizzeri, et al., 2019; Hostrup & Bangsbo, 2022).

The magnitude of a physiological response can be termed the 'dose-response' (Fitzpatrick, et al., 2018). The 'dose', or physical load applied to players can result in no change in physical development, maintenance of physical qualities, or can improve qualities. If practitioners can successfully understand the appropriate 'physical dose' to elicit a developmental 'physiological response', training can become optimised with focus on improving specific physical attributes, delivered with precision. It is the stimulus provided through the level of physical load that can impact its outcome. However, this fanciful notion is far more complex in practice. Research is presently limited, with available studies highlighting the presence of individual athlete responses, in addition to the sensitivity of results to the physical loading metrics examined, and the physical capacity tests used (Taylor, et al., 2016; Rabbani, et al., 2019; Younesi, et al., 2021).

The external loading is the physical output of players, such as the distance covered, load lifted, or quantity of high intensity actions performed at different speeds/intensities. External loading is the driver of internal loading, implying the physical activity completed, produces a corresponding psychophysiological response (Wing, 2018; Impellizzeri, et al., 2019). Internal loading is the physiological and psychological stresses placed upon an athlete in response to the external loading (Halson, 2014). The gross loading a player experiences can be categorised as match or training load. Across the soccer season, the soccer match regularly places the greatest physical and physiological demand on players (Anderson, et al., 2016). Match loading has been shown to be influenced by contextual factors including match location, the level of opposition, and match result (Castellano, et al., 2011; Andrzejewski, et al., 2016; Weston, 2018; Teixeira, et al., 2021).

Training load is also dependent upon many variables, including the volume and proximity of fixtures, the purpose and desired outcomes of training, and the phase of the season, amongst other variables (Kelly, et al., 2020; Hostrup & Bangsbo, 2022). Deliberate and planned alteration of physical loading to achieve desired physical and physiological outcomes, is known as periodisation (Los Arcos, et al., 2017). This can be done over a long term (e.g., seasonal) (macro-cycle), or over a single week (micro-cycle). The planning of this should allow for a gradual overload in physical stimuli of sufficient magnitude. This stimulus can elicit a physiological response, leading to physiological systems adaptation, and resulting in improved physical performance, through an increased capability to cope with the demands (Helgerud, et al., 2001). This stimulus can be focussed upon a specific physical attribute, such as strength or aerobic fitness, with variance in focus based upon contextual factors, namely time in season or proximity to a match. Specific phases within the season (mesocycle), such as pre-season, commonly features greater training load than any other phase of the season, due to the desire to improve the physical capacity of players, in preparation for the season (Jeong, et al., 2011).

For elite teams in-season, when fixture congestion is likely, soccer training may be tailored to allow players to recover from the physical demands of competing in up to three matches per week. During these weeks of double or triple games, the match demands itself may provide the 'training load', with training days supporting recovery, through a reduction in loading (Anderson, et al., 2016) for starting players. Training must also ensure players not featuring in these games are still provided ample physical stimuli to develop (Malone, et al., 2015). Non-starting players may be exposed to a 'training load' post-match or complete additional activities during training sessions. Whilst there is a desire to avoid physical overloading, due to the inherent injury risk associated with this condition, there is also the need to avoid players being physically underloaded, such as these non-starters. This physical unpreparedness may also occur due to a period of detraining, such as with an injury or break. Such conditions can lead to a lack of technical and tactical preparedness (FIFPRO, 2022), a reduction in physical capacities (Joo, 2018), and an increased injury risk (Gabbett, 2016; Malone, et al., 2017). This emphasises the need for careful monitoring of players' activity levels and involvement.

Within the microcycle, the training load is normally reflective of the proximity to and from matchdays (MD) (Malone, et al., 2015; Kelly, et al., 2020). The most demanding sessions are regularly completed around five to three days out from a game (MD-5 to MD-3), with a reduction in physical loading, or taper, nearer the game. This is completed to reduce the impact and likelihood of fatigue from training on match performance (Malone, et al., 2015; Anderson, et al., 2016; Owen, et al., 2017; Stevens, et al., 2017). Training sessions are composed of activities to develop all aspects of soccer performance. Physical development can be targeted within sessions through isolated conditioning, working only the physical aspect of soccer, or in combination training, where technical and/or tactical elements are incorporated within the drill (Hoff, et al., 2002; Moran, et al., 2019). The intensity, duration, and volume of these components can be altered, resulting in differing physical outputs and physiological responses (Impellizzeri, et al., 2019).

The concept of periodisation can also be extended to a players off-field strength and power training. Specific strength and power work, such as in resistance training, focused on developing muscular hypertrophy and/or force production can be used to develop a player's ability to perform on-field actions faster and with more force, such as changing direction or jumping (Turner, 2014; Silva, et al., 2015). As noted in the literature, the match demands introduce difficulty in implementing strength training in soccer due to the balancing requirements between training and development, with the need to be in a non-fatigued state entering matches (Silva, et al., 2015). This places a large emphasis on appropriate loading methods being implemented in strength and power training of soccer players.

Thus far, research has presented the immense demands placed upon soccer players and teams. Whilst training provides an opportunity to develop capacities required to support performance, it is important to understand just how impactful physical attributes can be to soccer performance. To assist in this enhancement of soccer performance through training, it is imperative to understand what factors may limit a players' ability to perform at their highest level. Through this understanding, data related to key physical characteristics can be collected. This information can be used to support the planning and delivery of targeted physical performance training.

2.5 Physical Factors Impacting Performance and Success

The ability of a soccer player to successfully compete is supported through their physical capabilities (Lago-Penas, et al., 2010; Lago-Penas, et al., 2011; Owen & Dellal, 2016). Whilst it is understood that other factors, such as technical and tactical ability likely exert a greater influence on success and match outcomes (Rampinini, et al., 2009; Di Salvo, et al., 2009; Modric, et al., 2022), the physical capacities of soccer players are still important to performance (Rampinini, et al., 2009; Rumpf, et al., 2016; Chmura, et al., 2022).

Through mitigation of these limiting factors, it is proposed that soccer performance could be improved, supporting club's chances of success.

2.5.1 The Potential Impact of Physical Capacity Upon Soccer Performance

The physical capacity of a soccer player is the maximal level of output for a given physical quality (e.g., aerobic endurance, maximal speed). Importantly, the capacity of a player should not be misinterpreted for their physical outputs within a match. Within matches, players are unlikely to reach this physical ceiling. These markers of physical activity, presented through metrics such as total distance covered, and at differing velocities, are not entirely reflective of what the player has the ability to do (Di Salvo, et al., 2012; Carling, 2013; Clemente, et al., 2019; Gomez-Piqueras, et al., 2019). Such investigations have also concluded that in most cases, the physical outputs of players within a match do not determine the outcome. Furthermore, greater physical outputs, such as increased distance covered in addition to increased distance at higher intensities, are not always related to a better performance (Di Salvo, et al., 2012; Carling, 2013; Clemente, et al., 2019; Gomez-Piqueras, et al., 2019). However, a player's physical capacity may influence the performance abilities of the player.

The analysis of physical capacities has identified trends between playing level of players, and performance and success. Within Hungarian and Norwegian top divisions, aerobic fitness and team performance have shown a clear correlation between greater aerobic capacity and improved final league standing (Apor, 1988; Wisloff, et al., 1998). A further study examining the effects of training to improve the aerobic endurance levels of soccer players highlighted the potential benefits of improved capacity (Helgerud, et al., 2001). Players who undertook specific aerobic training in addition to their soccer training recorded significant improvements in maximal oxygen uptake (VO_{2max}), lactate threshold and running economy in comparison to a control group, partaking in regular technical soccer training only. These improvements in aerobic endurance markers correlated with an increased number of sprints and ball involvements within matches following the training intervention. It should be noted however that this research is limited by the small participant group and number of matches analysed.

The difference between output and capacity has also been highlighted when examining the sprint ability of soccer players. Whilst the output of maximal sprint speed of players within matches across a season in the Spanish topflight has a “poor” relationship with the team’s final standing (Del Coso, et al., 2020), players must have the capacity to sprint and do so repeatedly (Chaouachi, et al., 2010). Activity profiles of soccer players suggest during matches most sprints are under 20m, indicating players are unlikely to reach their top speed. However, as these actions are repeated throughout the match, often with short recovery durations, the capacity to repeat these efforts is important. As such, repeated sprint ability (RSA) may influence success in soccer. Research has identified its ability to effectively discriminate between players competitive level (Impellizzeri, et al., 2008). Those possessing a greater capacity to maintain sprint speed across multiple repetitions, were seen to be playing at a higher level.

A similar finding has been shown when investigating maximal strength and power capacity. Whilst the maximal physical outputs of strength and power (e.g., 1 repetition max) may not be clearly associated with soccer performance, research supports that developing maximal strength and reactive strength levels can aid improvements in physical performance (Wisløff, et al., 2004; Falch, et al., 2019). A small sample study determined that the strength and power levels of players was a discriminating factor between performance level (Wisloff, et al., 1998). Despite this study only examining two clubs, the support of improving strength and power capacity is well backed in respect to improving a soccer players ability to perform physical actions, particularly fast and powerful movements (Silva, et al., 2015).

The research suggests that a soccer player and team, with developed physical characteristics promote their chances of success. This encourages the development of physical attributes through specific training modalities, aimed at increasing players' capacities. Players lacking in such qualities, may be targeted to complete additional or specific training to boost their qualities. However, the research also cautions the inappropriate use of data in determining outcomes. For example, the physical outputs of soccer matches are not sensitive enough to determine the winning team, or highlight the physical outputs required to be successful. Therefore, it would be inappropriate to target training for the goal of increasing physical outputs within a match. Rather, training should target the quality of improving a players capacity, allowing for the ability to complete more work, with a higher intensity, and/or lower physical cost (Hoff, 2005).

2.5.2 The Potential Impact of Fatigue and Injury Upon Soccer Performance

Another important limiting factor of soccer performance is fatigue and injury. Due to the high demand placed upon players during soccer, fatigue is likely. Fatigue is a decline in ones "physical and cognitive function", impacting upon the ability to perform at peak level. This may impact the muscles, whereby the physical demand is greater than the player's capability to perform the required actions (Nedlec, et al., 2012; Hader, et al., 2019; Dambroz, et al., 2022). This could be through the nervous systems inability to continue to activate the muscle to the appropriate level (Enoka & Duchateau, 2016). It may also be through a disruption to homeostatic conditions, impacting normal functioning. It has also been suggested that psychological factors may have an impact upon perceived fatigue levels, however this remains to be established (Enoka & Duchateau, 2016).

The impact of fatigue can be transient, such as after a short, but intense period of training or match play, where a brief period of recovery will allow normal muscular performance to return. Short lived fatigue has been shown to reduce running intensity immediately following a high intensity period or within the closing minutes of a game (Mohr, et al., 2003). Fatigue may also be accumulated due to the overall demand of the soccer match or training session. The level of fatigue experienced by players may also be exacerbated by the intensity at which training, or matches are completed, or through a lack of developed physical fitness characteristics (Paul, et al., 2014; Barte, et al., 2017). Dependent upon the extent of this physical demand, the reduced physical performance state may be longer lasting. This may require several days of recovery before muscular performance returns to normal levels (Mohr, et al., 2005; Nedlec, et al., 2012; Hader, et al., 2019).

In addition to impacting muscular performance, fatigue may also impact upon the technical abilities of players. Research across a multitude of sports and events, including soccer, have found that technical performance levels decrease following high intensity exercise (Davey, et al., 2002; Lyons, et al., 2006; Rampinini, et al., 2009). A systematic review of the impact of fatigue noted reductions in accuracy and speed of passing and shooting actions (Dambroz, et al., 2022). As referenced, the technical ability of soccer players is a major influence of performance (Rampinini, et al., 2009; Rumpf, et al., 2016).

Importantly and increasingly more frequently, is the reduction of the recovery period during congested fixtures (Dellal, et al., 2015; Gouttebarge, et al., 2019; Julian, et al., 2021). When surveyed, players also identified the substantial travel demands as having a significantly negative influence upon their performance and health (Gouttebarge, et al., 2019). It is therefore important that to avoid incomplete recovery, especially over extended periods resulting in nonfunctional overreaching, the impact of fatigue is understood and effectively monitored within soccer clubs (Haller, et al., 2022).

Fatigue can lead to heighted injury risk such as when an inappropriate physical stress is placed upon players whilst they are still recovering (Gabbett, 2016; Silva, et al., 2018). This is potentially due to fatigue altering movement/postural control and muscular strength levels which in turn detrimentally impact injury risk factors (Verschueren, et al., 2020). This may occur during a training week where the training sessions are too demanding and/or a demanding session is completed in proximity to a match. Performance staff and coaches must therefore ensure collaboration to tailor training sessions to an appropriate level of physical demand for the individual player.

During congested fixture schedules, evidence has suggested that despite no loss to overall physical outputs in the matches, injury rates may increase (Dupont, et al., 2010; Dellal, et al., 2015; Silva, et al., 2018). In one study (Dupont, et al., 2010), injury rates increased from 4.1 per 1000 hours to 25.6 per 1000 hours when two fixtures were in a single week, compared to one game only. The authors highlighted the primary injury classification was 'overuse', owing to the lack of sufficient recovery between matches. The lack of change in physical outputs has been suggested to be down to the large range of contextual factors that influence these values, including opposition level, style of play and location of the match. Despite this, recovery between matches may still be sufficient for some physical qualities to return, allowing for a similar physical output (Dupont, et al., 2010; Dellal, et al., 2015). This implies that the presence of 'typical' match outputs may act to mask the presence of fatigue within players. Present technology may not be sensitive enough to detect potential markers of fatigue. Additionally, the technology may not account for decrements in technical and tactical performance that may manifest from the presence of fatigue (Dambroz, et al., 2022). It is conceivable players continue to produce high physical outputs due to poor tactical decision making resulting in greater requirement for additional activity (e.g., distance covered), however research to confirm this would be required. This information stipulates that whilst training can be modified, it may also be worthwhile for coaches and performance staff to determine if a players match involvement is requiring manipulation to avoid this increased risk of injury.

The mitigation of injury risk is paramount in elite soccer for teams as they challenge for success. Research strongly endorses the notion that teams who keep their playing squad, in particular their best players injury free, are likely to be more successful (Arnason, et al., 2004; Eirale, et al., 2013; Hägglund, et al., 2013). An early study of Icelandic soccer teams identified a trend between injury incidence (i.e., injury frequency) and final league standing, with teams recording a lower incidence likely to finish higher (Arnason, et al., 2004). More recent investigations into injury incidence and success have shown analogous findings across both Qatari first division and elite European teams (Eirale, et al., 2013; Hägglund, et al., 2013). An examination of a professional French Ligue 1 squad detailed the key indicators of successful performance (Carling, et al., 2015). The most successful season presented a combination of low player utilisation, with only 84% of players featuring, in addition to the most players (10) completing 75% of total league minutes. Conversely, the seasons with the highest squad injury levels resulted in poorer league performance. A recent research article also explored the predicted loss of points through the loss of a team's two top performing players for half a season within the English Premier League. The potential loss of league points was up to 2.25 for one club, indicating the importance of keeping the top performing players injury free (Catapult Sports, 2022).

Research has also indicated that the progression from youth to senior soccer may be limited by injuries, with players with a high injury burden and low match availability less likely to advance to the first team (Larruskain, et al., 2022). Within youth soccer, this is a complex path to navigate, given the immense variability in individuals owed to biological maturation. Research has indicated that growth rate can influence the occurrence of overuse injuries (Rommers, et al., 2020). This is an important consideration due to the benefits of promoting talent from within the club, such as avoiding transfer costs.

Through a concerted effort to mitigate injury risk and incidence, by appropriate training, and understanding the impact of fatigue amongst other factors, soccer teams position themselves in a stronger position to be successful. Furthermore, by understanding the physical demands, and factors likely to limit performance, suitable monitoring, and preparation and physical development of soccer players can be undertaken (Dolci, et al., 2020; Balsom, et al., 2022).

2.6 How Physical Performance Data Can Support Soccer Performance

The effort to support soccer players and understand the impact of physical qualities on performance, has led to the development of 'sport science'. 'Science' has been present in soccer for decades, although the initial introduction is hard to precisely date. In their research detailing the scientific involvement within soccer, Drust and Green (2013) highlighted the use of scientific principles in soccer as early as 1960. In the intervening years, the involvement of science within soccer has grown.

Many professional soccer clubs now integrate science within their daily practice through the incorporation of 'sport scientists', within the staffing structure (Drust, 2019;

Nosek, et al., 2021). These specialist sport science practitioners are primarily drawn from academic backgrounds (Reilly & Gilbourne, 2003; Drust & Green, 2013). The role of these 'applied' practitioners is to oversee the physical performance aspect of the soccer players, in addition to any exploratory work related to this field. This investment in support staff has been concomitant with the increased financial investment in soccer and the desire of teams to increase their chances of success through the development of physical performance (Malone, et al., 2019; Drust, 2019). Due to the demands placed upon elite soccer players, physical performance staff play a role within the planning and execution phases, to best prepare players for competition (Reilly & Gilbourne, 2003; Drust & Green, 2013). These staff are tasked with developing the physical capabilities of soccer players, supporting the recovery process from physically taxing activities such as matches and training, in addition to alleviating the risk of injury (Sewell, et al., 2012; Drew, et al., 2017; Brink, et al., 2018).

To support these tasks, many sport scientists routinely collect physical performance data to support their work and inform decision making processes within their club (Nosek, et al., 2021; Evans, et al., 2022). The use of various technologies and assessment methods now form habitual practice within soccer clubs. Practitioners continually monitor their players' performance, readiness levels, physical activity, and response to exercise. This is completed to develop physical performance whilst also attempting to mitigating injury risk (Akenhead & Nassis, 2016; Bourdon, et al., 2017; Wing, 2018; Ryan, et al., 2021).

Performance monitoring is not a new idea, nor exclusive to soccer, with the general concept being applied in different settings, across a multitude of industries. An example of this stems from work by Henry and Dickey (1993), exploring educational reforms. They stated that performance monitoring use is twofold; firstly, it is used to assist in the development process, and secondly, to assess the impact of such change. This was succinctly put by the authors as describing the role of performance monitoring as being able to assist with ‘planning’ and ‘evaluation’.

The collection of physical performance data can be used to drive immediate or short-term decisions. It can also be the source of longer-term research to draw detailed insights from within the club, either independently, or in collaboration with research institutes (Coutts, 2017). The data collected by sport scientists can be used to inform decision making or drive research to provide a more detailed view of the impact certain practices, match demands, or training methodologies are having upon players physical status. This relationship between science and research in soccer, has been described as “fast” and “slow” work within clubs (Coutts, 2016; Coutts, 2017; Malone, et al., 2019). “Fast” work is viewed as that on a day-to-day basis, whereby the sport science staff, operating as part of the backroom team, make immediate decisions based upon experiential judgement and readily available data. “Slow” work is seen as that requiring further investigation and research, typically in conjunction with other members of performance staff, sometimes also involving academic researchers. This “slow” evidence-based research can yield important insights into a player or a team. However, for it to be of use to a club, it should be relevant to the needs of the team and players and then appropriately, and effectively, translated into practice (Coutts, 2017).

Data therefore must exist to allow for quick actionable information in the short term, in addition to be used for longer term research to provide insightful findings. As such, there is the requirement for efficient and accurate data collection and processing practices, using appropriate technology and methods, to be employed within clubs. This should be supported by expert staff who can use this information to draw out detailed insights.

2.7 Physical Performance Data Collection and Monitoring

Data collection processes have been buoyed by technological advancements, allowing for more precise and detailed insight of the team and players (Malone, et al., 2019; Almulla, et al., 2020; Evans, et al., 2022). Data collection in soccer can encapsulate all aspects of physical performance to provide a holistic overview of the team and players' physical profile. Despite no singular measure providing complete information regarding a player's physical status, the use of monitoring players' physical characteristics can still support decision making. This can be used to assist in determining a player's physical development plan, their readiness to perform, and back injury mitigation strategies, all qualities assimilated with limitations of soccer performance (Akenhead & Nassis, 2016).

The desire to understand players' physical status and support this decision-making process has resulted in a myriad of monitoring systems now being present within soccer clubs, with new technology still emerging. This creates uncertainty around the areas of physical performance monitoring and the methods of data collection professional soccer teams currently employ. Despite efforts to explore club's data monitoring practices, due to the expansive nature of physical performance, the current landscape is not well established.

2.8 Physical Load Monitoring

To assess the demand of a soccer activity, physical load monitoring can be used. Viewed as external load (physical activity) and internal load (psychophysiological response), these areas of physical performance are the most monitored within soccer, as per research examining domestic soccer teams across the globe (Akenhead & Nassis, 2016). Performance practitioners have identified the purpose of monitoring training load as assisting in designing training sessions, maximising performance, enhancing fitness levels, and mitigating injury risk (Nosek, et al., 2021; Weston, 2018).

Both loading areas can be viewed individually, however, when used in conjunction, can provide insights into the fitness of soccer players (Castagna, et al., 2011). This highlights the relationship between both areas of physical performance monitoring, whereby external loading results in a psychophysiological response (internal) (Impellizzeri, et al., 2019). The internal loading is the primary driver of physiological adaption, where consistent exposure to a physical stimulus of sufficient magnitude, can result in adaptation to the stimulus, and improvement of physical characteristics. Where similar external loading values exist, with differing internal responses, it is suggested that differences in fitness levels may exist (Impellizzeri, et al., 2019).

Due to the close association, external loading is a commonly used metric in the periodisation process. Periodisation utilises variations in the external load players are exposed to, to optimise the physical and physiological response and outcomes (Bradley, 2022). This use of prescribing parameters to drive the external demand to stimulate an internal response may be viewed within training sessions. This can be seen through the changes in training components, such as training game pitch dimensions, training numbers, and work to rest ratios (Owen, et al., 2012; Owen, et al., 2014; Clubb, et al., 2022). Periodisation is also seen in variations in physical loading across training weeks, and seasonal phases. These alterations to physical demands have been shown to elicit improvements in physical performance. Such external demands that result in athletes reaching 90% maximal heart rate (HR) or above, has been attributed to significant improvements in athlete's maximal oxygen uptake levels (McMillan, et al., 2005). With aerobic fitness being an important attribute to develop in elite soccer, monitoring of such training stimulus is crucial to ensure the players' aerobic capacity is developed to cope with the demands of the sport (Apor, 1988; Wisloff, et al., 1998; Helgerud, et al., 2001).

From an injury mitigation standpoint, monitoring can ensure exposure to specific activity has occurred. One example involves players regularly achieving sprint speeds >95% of their individual maximal sprinting speed, combined with a high chronic training load (Malone, et al., 2017). However, excessive, or inadequate exposure to either of these variables may itself present an injury risk (Gabbett, 2016). Load monitoring can assist with the tracking of these outputs, supporting practitioner decision making. One method of monitoring this physical loading involves the use of the acute: chronic work ratio (ACWR), where historical physical load across the previous training weeks (fitness) is compared to the most recent training days physical loading (fatigue) (Gabbett, 2016). Research has suggested that a ratio of over 1.5 (fatigue: fitness) is linked to increased injury risk (Gabbett, 2016), whereas players with a loading ratio of between 1.00 and 1.25 were at a significantly reduced injury risk (Malone, et al., 2017). However, recent work has challenged the concept that supports this monitoring method (Impellizzeri, et al., 2020). These conflicting findings further challenge practitioners to apply appropriate methods of monitoring. Recent work has also highlighted the potential importance of regular exposure to high intensity deceleration actions to be performed as a training tool to prepare athletes for competition. However, caution is warranted around overloading in the early phase of training, where the athlete is physically not prepared to deal with these demanding forces (Harper, et al., 2019; McBurnie, et al., 2022). Therefore, careful monitoring and manipulation of physical loading can be used to develop players' physical capacities, in addition to providing the appropriate physical stimulus to avoid increasing their risk of non-contact injuries.

The most frequent method of monitoring external loading in elite soccer is player worn microelectromechanical devices, featuring integrated Global Positioning Systems (GPS) (Akenhead & Nassis, 2016; Weston, 2018; Clubb, et al., 2022). GPS systems have been validated and have shown good interunit reliability, when assessing physical activity (Johnston, et al., 2013; Clavel, et al., 2022). Other methods of collecting time-motion analysis data relating to external loading exist, such as digital video player tracking systems (SportVU®) and local position measurements (LPM) (Inmotio®) (Halson, 2014; Buchheit, et al., 2014). Internal loading is commonly monitored using heart rate monitors (Akenhead & Nassis, 2016), however, other methods exist. Biochemical markers (e.g., blood lactate) can also be used in the determination of training levels, such as the intensity of an athlete's activity to produce a desired physiological response. Subjective rating of perceived exertion levels (RPE) may also provide a cheap and simple method of collecting players interpretation of the session demand (Akenhead & Nassis, 2016).

2.9 Player Readiness to Train Data

Soccer matches and training to improve physical capacities can result in fatigue, transiently impairing performance (Mohr, et al., 2003; Mohr, et al., 2005; Nedlec, et al., 2012; Hader, et al., 2019). The role of physical performance staff is to ensure players' do not progress to a severely depleted state (e.g., overtraining syndrome) where injury risk and decline in performance is amplified (Saw, et al., 2016; Heidari, et al., 2019). Therefore, knowledge of a player's readiness to perform and how they respond to physical bouts is an important insight. Through the monitoring of areas associated to a player's 'readiness' or 'recovered' status, decisions regarding training content and physical loading, recovery strategies, and appropriate interventions can be implemented (Buchheit, 2014; Heidari, et al., 2019; Balsom, et al., 2022; Gregson, et al., 2022).

Assessment of readiness can involve simple self-completed questionnaires documenting player's perception of their sleep quality, recovered status, residual fatigue, and soreness amongst many other possible items (Gastin, et al., 2012; Noon, et al., 2015; Saw, et al., 2016). These questionnaires have been shown to correlate with physical demands and psychological stresses presented across a soccer season (Noon, et al., 2015). A review of the use of subjective assessment of wellbeing and readiness indicated the sensitivity of questionnaires to both acute and chronic physical loading (Saw, et al., 2016). Furthermore, associations between subjective wellbeing and subsequent injury have been demonstrated within adolescent elite athletes, whereby a decrease in subjective scoring preceded an injury (von Rosen & Heijne, 2021). Despite the positive use associated with subjective monitoring, limitations have been raised. It has been highlighted that many practitioners do not employ validated questionnaires, rather, opt for custom made surveys (Neupert, et al., 2022). This may be due to a lack of knowledge within the monitoring area, or due to time constraints. This has also resulted in non-uniformity within the monitoring landscape resulting in the potential for practitioners to devise imprecise and ambiguous question sets (Neupert, et al., 2022). Furthermore, many questionnaires are presented to athletes using mobile devices, which has also presented barriers to effective use. Athlete engagement has been shown to be low within some studies (Saw, et al., 2015), in addition to the perception that the reporting is part of "hostile surveillance" (Manley & Williams, 2022).

Due to the disruption to biological homeostasis, assessments can also be made using deviation from fully rested state values. Assessments of heart rate at resting state (e.g., heart rate variability), detecting changes in the autonomic nervous system, have been noted as time-efficient and inexpensive, however, can be influenced by time of day and environmental conditions (Buchheit, 2014). Biochemical analysis of bodily fluids (e.g., blood, urine, saliva) can identify markers related to the stresses induced through exercise (Heidari, et al., 2019). Elevated levels of creatine kinase for example can signal the presence of muscle damage, and monitoring of these levels can provide an insight into the recovery period of players. Physical tests, such as a countermovement jump, have also been researched in relation to their ability to highlight fatigue and the recovery status of players (Nedlec, et al., 2012; Doeven, et al., 2018; Fitzpatrick, et al., 2021). Alterations to an individual's jump profile may indicate fatigue is present and recovery is incomplete, necessitating a change to planned physical loading, or the use of recovery interventions (Doeven, et al., 2018; Fitzpatrick, et al., 2021). Research has highlighted the use of these methods within professional soccer, displaying variance of process use and frequency of collection (Harper, et al., 2019). Despite technological advances allowing for simple to administer testing, and efficient interpretation of results, use of available methods has been shown to vary based upon current research, cost, and available facilities within clubs (Harper, et al., 2019). To support development of this important monitoring area, identification of current methods is therefore important to establish.

2.10 Physical Performance Testing

Due to the importance of physical attributes to soccer performance, assessment of a player's physical capacities can provide important insights (Hoff, 2005; Taylor, et al., 2022). These assessments of physical performance capabilities can be used to identify areas of weakness where targeted interventions (training) could support physical development, or injury mitigation. This data also provides objective information to support further decisions such as recruitment and talent identification (Taylor, et al., 2022). Assessment can also be used to monitor the impact of an intervention, such as assessing changes in physical fitness, or assess the influence of a recovery modality on a player's readiness to train status. Development of physical attributes, confirmed through assessment of physical capacities, could provide a benefit to performance and a reduction in player injury risk (Paul & Nassis, 2015). For example, elevated aerobic and anaerobic fitness levels have been associated with greater success and performance levels (Helgerud, et al., 2001; Impellizzeri, et al., 2008). Conversely, imbalances in strength likely increase the risk of injury (Paul & Nassis, 2015).

Physical performance testing can range from simple full squad field-based tests to expensive and more time-consuming individual laboratory/gym-based assessments (Paul & Nassis, 2015; Taylor, et al., 2022). Due to the advances in technology and clubs investing in equipment to support their performance and medical departments, elite teams now have access to many items of specialist testing apparatus allowing for collection of data relating to all aspects of physical performance. Research examining testing practices highlighted strength and aerobic fitness testing as the most monitored performance capacities (Asimakidis, et al., 2024). These were followed by power and linear speed. Player fitness levels can be assessed using incrementally graded exercises tests on a treadmill, or more suitable for the team environment, through the field-based alternatives of time trials (e.g., 1200m), timed distance runs, and intermittent protocols (e.g., 30:15 intermittent fitness test (IFT), yo-yo intermittent recovery test (YYIRT)) (Taylor, et al., 2022; Asimakidis, et al., 2024). Due to the physical demands already imposed upon players, one increasingly popular method of assessing changes in fitness is the use of sub-maximal protocols and the evaluation of heart rate response to this (Taylor, et al., 2022).

This allows data to be collected through less physically demanding and time-consuming means.

High intensity actions such as sprinting and change of direction/agility can be assessed through tests at maximal effort across set distances/courses. Technology such as photocell timing gates can allow for recording of duration to complete the activities, and splits of the total time can provide an insight into different phases of the action, such as breaking a maximal forty metre sprint into acceleration and maximal speed phases (Taylor, et al., 2022; Asimakidis, et al., 2024). Photocell timing gates have provided practitioners with a relatively inexpensive and accurate method of monitoring sprint times, compared to expensive and likely inaccessible gold-standard fully automated timing systems (Haugen & Buchheit, 2016; Colino, et al., 2019). Additional physical performance markers, such as power and strength may be monitored through force platforms, jump mats, and force transducers (Bishop, et al., 2022). Common tests of these qualities include the isometric mid-thigh pull, Nordic hamstring strength test, and adductor strength groin squeeze test (Asimakidis, et al., 2024). This extensive testing is possible due to the now easy accessibility of laboratory grade physical performance testing equipment, of high reliability and accuracy (Merrigan, et al., 2021; Ferguson, et al., 2023).

Assessment of performance may also extend to training within gym-based sessions, such as using velocity-based training (VBT) tools. This method involves the collection of the speed or power at which exercise repetitions are completed. Such a monitoring tool may be used to determine optimal training loads for varying training stimulus (i.e., strength or speed), limit fatigue as measured through loss of speed/power, and may also serve as motivation for athletes (Włodarczyk, et al., 2021; Thompson, et al., 2022).

Devices for monitoring such gym-based performance include linear positional transducers, inertial measurement units, and camera systems (Thompson, et al., 2022).

Body composition is another area that may be assessed for performance assessment purposes. The physical profile of a player has the potential to impact their physical ability and subsequent performance level. Whereas skeletal muscle can assist in force production, body fat can negatively impact upon aerobic fitness and athlete's "power-to-weight ratio", both important qualities for soccer performance (Carling & Orhant, 2010; Collins, et al., 2021; Martinez-Ferran, et al., 2022). Assessment of an individual's body composition can be conducted through several methods, from simple cost-effective skinfold assessment, to more costly, time consuming dual x-ray absorptiometry (DEXA) (Turner, et al., 2011; Martinez-Ferran, et al., 2022). This information can be used to inform club performance and nutrition practitioners decision making regarding a player's training plan to increase lean muscle mass or reduce fat mass. Additionally, this information can also help shape nutritional guidance to players in relation to their required fuelling strategies for matches and training (Carling & Orhant, 2010).

2.11 Storage and Processing of Physical Performance Data

Beyond the collection of physical performance data, is the need to store and analyse data to facilitate the extraction of any valuable insights. The rapid expansion of physical performance monitoring in recent years has highlighted the need for soccer clubs to have comprehensive data management systems in place to deal with the multiple sources of information (Evans, et al., 2022; Newell, et al., 2022). Modern solutions, such as 'athlete management systems' (AMS) acting as centralised platforms to consolidate information from multiple areas of physical performance into one complete data bank have been created to solve this data management issue. However, whilst these systems exist, it remains unclear as to how clubs at the elite level currently operate these platforms.

To better understand data processing and analysis within soccer, one can explore another department in soccer teams that has also experienced a boom in data accessibility, performance (video) analysis. Like sport science, performance analysts collect a large variety of data, including video footage, observational data, statistical outputs, and physical information to inform upon decisions relating to the tactical setups of teams (Rein & Memmert, 2016). Performance analysis is now frequently associated with the term "big data" referring to large volume of data, of a wide variety, and produced at a high velocity (3 V's) (Rein & Memmert, 2016). Whilst no method of data storage has been established, research in performance analysis has leaned on other data handling domains, such as medicine. A "technological stack" for analysis as proposed by Rein and Memmert (2016), incorporates the multiple levels required to collect, merge, store, and "extract" valuable information from the multiple facets of data monitoring. The authors note the requirement for knowledgeable individuals to facilitate the operating of such a data handling system, necessitating individuals with an extensive understanding of computer systems, as opposed to physiological systems, indicating an emerging category of soccer practitioner.

Returning to physical performance, analysis of stored data can provide the opportunity for a more detailed level of insight. This is completed through the addition of context to raw values, such as through comparison to normative data, other players within the team, or performance targets, amongst numerous other possibilities (Newell, et al., 2022; Asimakidis, et al., 2024). Data analysis can also be applied to the individual within a team, to identify a single players physical response or capacity, which may be hidden if processed with all team data (Ward, et al., 2018).

There are many processes associated with the analysis of collected information. Data can be transformed from absolute values into relative values and be compared to the physical demands of a match or loading history (Drust & Dalen-Lorentsen, 2022). This may allow for target setting or support the periodisation of physical load during training. Statistical analysis methods, including repeated measures and Bayesian modelling have been listed in research, highlighting the depth of analysis that can be conducted upon data (Newell, et al., 2022). To determine changes within player data, research has supported the use of magnitude-based decisions as an appropriate statistical method (Ward, et al., 2018; Malone, et al., 2019). Modern methods have seen the integration of machine learning to the analysis process to further enhance the investigative capabilities of club-based data analysis (Buchanan, 2023).

Concerns have been raised regarding the analytical processes currently employed within soccer (Asimakidis, et al., 2024). When examining physical capacity testing, comparison to previous results was a key insight produced by many practitioners (Ward, et al., 2018; Asimakidis, et al., 2024). However, under half of practitioners calculated measurement error for this finding, limiting the value of the insight. Additionally, it was highlighted that most practitioners (95% of surveyed 73) used a standard computer package, such as Microsoft Excel to analyse their data (Asimakidis, et al., 2024). Only around a quarter of practitioners utilised a more advanced statistical software or coding platform. This likely suggests that data analysis practices are likely not extracting insights to a great level of detail across soccer clubs.

Research by Ward, Windt, and Kempton (2019) discussed the principle of data analysis, when exploring the role of sport science in “organization decision making”. Key to their presentation of this idea was the use of “business intelligence” to support stakeholders and other departments within the club. This stressed the thorough processes that should be implemented for data collection and beyond this, the “fast” or “slow” analysis required for the decision at hand. Such analysis should implement appropriate methods and models, whilst respecting the limitations owed to personal knowledge and the methods of analysis employed.

Whilst the possibilities of analysis are potentially limitless, the use of metrics and statistical measures must be related to the performance-based questions requiring answered within soccer clubs (Impellizzeri, et al., 2019; Malone, et al., 2019; Evans, et al., 2022; Newell, et al., 2022). The questions posed by clubs will vary based upon level of competition, strategy targets and stakeholders views and experiences. It is this natural variance in intrigue and drive that has led to data collection and analysis in soccer as having “no uniform picture” and being fragmented (Evans, et al., 2022). This presents a similar overview to data collection, where the overall landscape is not well understood. Ultimately, data processing and analysis should yield informative insights that can be used to not only benefit the decision making of the sport science department but could be used to benefit other stakeholders. However, this benefit is limited by the ability to communicate this information to these stakeholders.

2.12 Data Feedback and Communication within Clubs

To support practice, performance practitioners share their collected information with key stakeholders, including coaching and medical staff (Weston, 2018; Nosek, et al., 2021). This allows data to be accessible by the relevant staff, assisting in decision making throughout clubs. Research has examined this process, exploring the use of data and the issues related to translation of scientific information to comprehensible and actionable decisions.

Physical performance data has been viewed as “somewhat important” in influencing the design of training, development of fitness, mitigation of injury, and the “assessment of effort” (Nosek, et al., 2021). Most coaches (85%) reported they met with their sport science department between one and three times per week to review training content and physical outputs (Nosek, et al., 2021). These meetings primarily occurred prior to training, informally, or to discuss impactful events (e.g., injury), with coaches finding these discussions “very valuable”.

Whilst most coaching and performance staff find information such as training load monitoring beneficial to the training at their clubs, concerningly, these staff flagged areas of weakness with performance data sharing, including information overload, poor communication, and a lack of a unified approach. Such breakdown in communication may impede the implementation of actionable responses based upon physical performance data supported decisions (Nosek, et al., 2021). Consequences of this can be detrimental to soccer teams, impacting player availability and injury risk, both of which may impact the success of the club (McCall, et al., 2016; Ekstrand, et al., 2019).

A study into the considerations when applying technology in a sporting setting addressed this issue by stating “technology does not inherently communicate a message” (Windt, et al., 2020). The authors identified that whilst data can be appropriately collected, analysed, and presented, this does not guarantee a fully comprehensible understanding for all stakeholders. Caution and care must be taken to ensure that findings are translated in relation to the questions that require to be answered, as well as disseminated in a manner that can be understood. Additionally, with all feedback, there is the need for rapport and trust between those giving, and those receiving the information (Buchheit, 2017; Ward, et al., 2019). Trust may lead to a more impactful outcome, with greater ‘buy-in’ from the stakeholder.

It is also important to understand the methods of providing feedback. Communication of information can be completed visually or verbally (Weston, 2018; Ward, et al., 2019; Nosek, et al., 2021). Visualisation should be easy to understand and appealing to look at for stakeholders, whilst presenting information directly attributed to the physical status/output of players (Lacome, et al., 2018).

Feedback of information holds the power to successfully inform key messages to stakeholders involved with player development. These messages can influence decision making related to planning for training and injury mitigation. Due to the continued research backed findings highlighting feedback concerns, it is paramount that development of methods aimed at improving this translation of informative findings into effective practice continues.

2.13 Physical Performance Data Limitations

The advances and increased access to monitoring technology, combined with the desire of performance practitioners to gain a greater insight into their players has resulted in vast quantities of data now being collected. The volume of information is magnified when considering the frequency with which it is collected using a variety of monitoring tools (Akenhead & Nassis, 2016; Malone, et al., 2019; Drust & Dalen-Lorentsen, 2022; Evans, et al., 2022). This has led to an abundance of monitored metrics, some specific to the individual companies monitoring system. This can result in quantity over quality with regards to the data collected within soccer clubs.

To improve the efficacy of data monitoring, soccer clubs require appropriate staffing in place to support monitoring practices (Rojas-Valverde, et al., 2019; Windt, et al., 2020). This should be in the form of sport scientists aware of data demands and analytical procedures, or specialist data practitioners (e.g., data analyst) (Rein & Memmert, 2016). A lack of specialist staff may increase the burden placed upon practitioners already completing other roles, damaging the value of the monitoring process, and potentially resulting in poor return for investment in the technology.

The access to substantial amounts of data creates the ability for practitioners to collate large data sets first, and then analyse the data, with the hope of producing insights. However, due to the quantity of information and the potential misunderstanding of collected metrics, practitioners should first address the issue they aim to solve, and then identify the information that will assist this process (Bishop, 2008). By first understanding the issue to be solved, data collection efficiency could be improved.

Ensuring appropriate metrics are collected is also vital as research has proposed the potential that much of the collected data can potentially overlap. This means that many metrics may be detailing the same physical concept (Ryan, et al., 2021). This "collinearity" may falsely emphasise findings due to the close relationship between many of the metrics (Ryan, et al., 2021). Findings may therefore be inadvertently concluded, or strengthened, resulting in improper decision making.

The current collected information may also not be appropriately describing the physical actions of a player. In the case of physical load monitoring, the collection of "oversimplified" metrics may reduce the contextual understanding of how players achieve their physical outputs and physiological response (e.g., maximal sprint speed in a curved run) (Filter, et al., 2023). This is an emerging area of physical performance monitoring, whereby data is combined with tactical detail or video analysis to provide circumstantial information in addition to physical information (Bradley & Ade, 2018; Bradley, et al., 2018).

From these concerns, it is evident that data produces vast outputs, that must be successfully navigated by practitioners if they are to yield effective outcomes. If these concerns can be mitigated, the future landscape of physical performance monitoring in soccer could be improved, resulting in greater support provided to players and clubs as they navigate the extreme challenges placed upon them by the modern game. Therefore, research must continue in the effort of identifying key performance insights, assisting in the improvement of the data monitoring processes.

2.14 Research Summary

Soccer presents a physically demanding environment, through extensive travel, congested fixture schedules, and increasing match demands. The role of performance practitioners within soccer clubs is to support the player development process. They do this by ensuring their squad can cope with these demands and attempt to maintain their players' availability through injury mitigation strategies. Practitioners support their role through the collection physical performance data regarding their physical status. This information can then be used to support decision making relating to physical performance. This could assist in the planning and the management of players' needs, based upon a multifactorial approach, including physical readiness and developmental requirements.

However, it is currently not clear what data processes are currently implemented within professional soccer clubs due to the vast number of methods and technologies that presently exist. Whilst research has aimed to explore individual channels of physical performance, there exists no understanding of the entire monitoring landscape. Furthermore, due to the natural variance in intrigue and drive that has led to performance monitoring, the metrics collected and processed appear to have no “uniform picture”. This may result in inappropriate methods being used, limiting the effectiveness of the collected data. Due to the vast number of methods available, it is paramount that practitioners can identify key insights to provide informative information to support the decision-making processes within professional soccer clubs.

Finally, despite ongoing research examining data monitoring and its use, limitation in the feedback of this information to stakeholders continues. Whilst efforts have been made to improve these processes, it appears that these are not being successfully implemented within professional soccer. This can reduce the overall efficacy of the monitoring process.

PHASE 1 – PHYSICAL PERFORMANCE LANDSCAPE

CHAPTER 3:

A MULTI-CLUB EXPLORATION INTO THE STRUCTURE, COLLECTION, PROCESSING, AND USE OF PHYSICAL PERFORMANCE MONITORING DATA WITHIN PROFESSIONAL SOCCER

3.1 Introduction

In the elite echelons of soccer, success often delivers lucrative financial rewards, key to clubs remaining competitive. This allows for further investment of these finances into the playing squad, and supporting structure (e.g., backroom staff and facilities) (Menary, 2016; Deloitte, 2019; Georgievski, et al., 2019; Malone, et al., 2019). The physical ability of a team's players is one of many facets that may determine this success (Arnason, et al., 2004; Lago-Penas, et al., 2010; Lago-Penas, et al., 2011; Bangsbo, 2015; Owen & Dellal, 2016). Squads with developed physical attributes (Apor, 1988; Wisloff, et al., 1998; Rampinini, et al., 2009) and low injury rates (Arnason, et al., 2004; Eirale, et al., 2013; Hägglund, et al., 2013) have been shown to have a greater likelihood of being successful. However, with soccer seasons typically lasting around 10-11 months (Malone, et al., 2015; Silva, et al., 2016) containing demanding travel and fixture congestion (Carling, et al., 2012; Ekstrand, et al., 2016; FIFPRO, 2021; FIFPRO, 2023), the ability to physically develop athletes, and mitigate injury risk is becoming increasingly challenging (Dupont, et al., 2010; Dellal, et al., 2015; Gabbett, 2016; Silva, et al., 2018). To support players throughout this process, clubs employ sport science/physical performance staff to oversee the players' physical loading, and development (Akenhead & Nassis, 2016; Bourdon, et al., 2017; Wing, 2018; Drust, 2019; Ryan, et al., 2021). These physical performance practitioners routinely collect various channels of data pertaining to the physical status of their players, through a multitude of technologies and testing methods (Weaving, et al., 2019; Nosek, et al., 2021; Evans, et al., 2022). However, very little is currently known about the procedures and processes supporting physical performance data monitoring. This extends to the methods employed for collection, analysis, feedback, and the influence this information has upon decision making within soccer clubs.

Monitoring practices have developed at a rapid pace, supported by technological advancements (Malone, et al., 2020; Almulla, et al., 2020; Evans, et al., 2022). This has allowed for an increased ability to collect information regarding the physical status of soccer players. These insights can explore players' physical profile, namely their readiness to train (Saw, et al., 2016; Carling, et al., 2018), physical loading experienced during training and matches (Akenhead & Nassis, 2016), and their physical capacities (e.g., speed, power, and fitness) (Turner, et al., 2011; Carling & Collins, 2014; Paul & Nassis, 2015). This information can be used to support decision making within a soccer club, in relation to the physical performance of soccer players. This may involve the planning of a player's physical loading, and altering player training focus during congested fixture periods (Mohr, et al., 2005; Nedlec, et al., 2012; Malone, et al., 2015; Anderson, et al., 2016; Hader, et al., 2019; FIFPRO, 2022; Newell, et al., 2022; Balsom, et al., 2022). It can also be used to plan training development programmes for players to improve physical capacities aimed at enhancing performance and mitigating injury risk injury (Nosek, et al., 2021; Taylor, et al., 2022). However, due to the rapid development of monitoring technologies and practices, issues relating to the implementation, efficiency, and effectiveness of monitored data are arising. For clubs to operate player monitoring, particularly those collecting multiple streams of physical performance data, it is important there is a supporting structure to accommodate the effective implementation of these practices. Firstly, there needs to be appropriate staff to facilitate the incorporation of technology and data collection methods (Rein & Memmert, 2016; Rojas-Valverde, et al., 2019). Without such a structure, operations related to the collection, storage, and analysis of the information may be ineffective or inefficient (Newell, et al., 2022).

Concern has also been raised around a lack of consensus regarding important and influential metrics. It has been reported that "over 50" metrics are being used across elite soccer clubs to aid with "load monitoring" (Akenhead & Nassis, 2016). Many of these metrics may be unsupported in their use, and several may be presenting very similar insights, leading to possible confusion amongst practitioners, or erroneous findings (Weaving, et al., 2019; Ryan, et al., 2021).

To support this collected data, research has suggested potential methods of data management (e.g., AMS) (Newell, et al., 2022). Incorporation of this software may allow for data to be connected, assisting in better informed decisions, using data from multiple areas of physical performance. The AMS may also support an efficient method of analysis and feedback, not requiring the construction of self-built data storage and processing worksheets. Despite these benefits, very little is known about current data storage and processing practices within clubs. Of the limited research, it appears there is a lack of appropriate software being used to process data (Asimakidis, et al., 2024).

Also concerning, coaching and performance staff have flagged several areas of weakness with performance data sharing. This includes the overloading of information within feedback, poor communication, and a lack of a unified goal. Such breakdown in communication may impede the implementation of actionable responses based upon physical performance data supported decisions (Nosek, et al., 2021). A consequence of this, could see heightened increased risk, an outcome that may impact a club's success (McCall, et al., 2016).

Due to the importance of ensuring physical performance monitoring is effective in its support of assisting in decision making processes within clubs, it is important to establish the landscape of current data monitoring practices within soccer clubs. This research project therefore aims to explore a cross-sectional overview of the current physical performance data collection, analysis, feedback processes, in addition to practitioner opinion regarding current practices.

3.2 Methods

3.2.1 Study Design

Utilising an online survey, the study collected responses from performance practitioners working within full-time soccer clubs. The survey collected responses on multiple topics, aiming to better understand the current landscape of physical performance data within soccer. Free text responses documenting practitioner opinions were used to add qualitative support. Results from the surveys were then analysed to provide insights regarding data collection, analysis, and feedback processes.

3.2.2 Survey Design

The survey was created exclusively for this research project, using a secure online survey platform (LimeSurvey, Hamburg, Germany). The aim was to explore the full spectrum of physical performance data in professional soccer, inclusive of the data collected, monitoring tools used and methods of processing and feedback. The cross-sectional self-completed survey (see Appendix 1), answered online, consisted of one participant consent and five sections exploring the responding practitioner's experience and opinion on physical performance, and physical performance data in professional soccer (e.g., participant information, current monitoring practice, data processing, data feedback and practitioner opinion). The survey focused upon ten areas of performance monitoring, drawing these areas from previous research (external load, internal load, RPE, wellbeing, physical capacity, body composition, neuromuscular fatigue, biochemical analysis, and internal fatigue monitoring), in addition to researcher judgement (Ward, et al., 2018). Whilst these areas likely contain different technologies, methods of monitoring, processing, analysis and feedback, the grouping of these performance areas was completed to allow for easier post-collection comparison. Additionally, it allowed for the categorisation of answers, aiding reporting of results. To avoid areas of performance monitoring being missed, 'other' categories were included. This allowed respondents to highlight any areas not adequately covered by the pre-determined categories.

The survey contained twenty-four questions with responses collected via a combination of open, closed, scaled (5-point Likert), and ranked formats (Gratton & Jones, 2010). The Likert scale used within the survey featured verbal anchors (1 - Never; 2 - Rarely; 3 - Sometimes; 4 - Often; 5 – Always). Responses were ranked ascendingly to avoid potential response order effects (Chyng, et al., 2018). Ethical approval for the study was granted by University of Birmingham's ethics committee (ERN_2022-0259).

Prior to release, the survey was reviewed by two individuals. An experienced university lecturer provided written and verbal feedback within the survey development process, to assist with the readability and structuring. A current researcher and sport science practitioner, familiar with this method of data collection, also provided written and verbal feedback regarding the readability and structure of the survey questions. Two sport science practitioners then completed the survey to provide information regarding usability and sample answers. This process of assessing the survey content for legibility and validity has previously been used in research (Stoszkowski & Collins, 2016; Weston, 2018). Following the review of the survey structure and content, several questions were removed or amalgamated to reduce the survey length and increase readability. Some questions were also altered in their wording as they were deemed to be 'leading' (Webb, 2022). After submission of the two trial surveys, the responses were reviewed by the research group and the survey deemed ready for distribution.

3.2.3 Survey Dissemination

Survey distribution was conducted using a two-phase approach, (1) an initial targeted approach followed by (2) a wider non-directional social media campaign. For the targeted approach, the survey was emailed to members of the research groups professional network of sport science practitioners. 'Snowball sampling' was used within this method of convenience sampling to boost response numbers, by inviting those initially contacted to share the survey with members of their professional network, who also met the eligibility criteria (Morgan, 2008). The survey was emailed to prospective participants with an accompanying semi-personalised introductory message, in addition to the participant information sheet and project synopsis (see Appendix 2). Follow-up reminder emails were sent to all participants two and four weeks after the initial contact.

The social media campaign was carried out across two platforms (Twitter (now X), California, USA, and LinkedIn, California, USA), across an eight-week period from September 2022 to November 2022. To utilise 'snowball sampling' within this process, posts on the social medial platforms encouraged participant recruitment (professional network and social media) by requesting individuals to further distribute the survey to eligible participants (Morgan, 2008). Participants were informed that contribution to the survey was entirely voluntary, and any submission could be withdrawn without cause, for up to seven days following their submission.

Due to the method of dissemination including snowball sampling, it is not possible to provide a response rate for this research. However, the number of respondents is known, with 63 practitioners returning their survey. This is a similar completion number to a frequently referenced research article examining a similar topic, where 41 questionnaire submissions were examined (Akenhead & Nassis, 2016). As not to compromise the anonymity of the respondents and their clubs, no information was collected on the club other than the level of competition or academy rating. This however, made targeted follow up emails to non-respondents difficult, as individual responses could not be identified without the participant confirming their response date and time as identification.

3.2.4 Participants

A total of 63 respondents provided submissions for the questionnaire. The average experience of practitioners was 8 ± 5 years within professional soccer. There were 30 respondents who included 'sport science' in their job title, four with 'data', 23 with 'physical performance/athletic/fitness' and six with 'strength and conditioning'. The seniority level of those included was classified as 'senior' (n = 1), 'head' (n = 23), 'lead' (n = 6), 'regular' (n = 32) and 'assistant' (n = 1), providing a varied participant job role and experience level for the results. There were 33 respondents from 'academies' and 30 from 'senior' squads. A total of 28 respondents worked for a club within the Elite Player Performance Plan (EPPP) in the Premier League system, 30 were from 'professional' senior clubs, three responses were from club academy Scotland (CAS) teams, and two were from 'other'.

Due to certain survey sections being optional, or not relevant to all practitioners, respondent numbers ranged per section, with the respondent values for each section being expressed within the results. Similar fluctuation in responses per section of surveys can be seen in previous literature (McCall, et al., 2016). Criteria for inclusion was performance practitioners working full-time with a professional (full-time) team (youth or senior) as part of a department of more than one full-time practitioner. The primary locus of respondents was the United Kingdom, however, to increase response rates, submissions from other regions were accepted, providing the eligibility criteria was met. It was estimated that 60 clubs within the United Kingdom (English Premier Legue, English Football League, Scottish Premier League) met the eligibility criteria. This allowed for one senior squad and one professional academy squad practitioner being able to complete the survey, resulting in 120 possible respondents, with the addition of some global respondents. Academy and senior team practitioners of the same clubs were accepted due to the possibility of different monitoring practices, including technologies and methods of implementation. These target clubs were compiled based upon their academy categorisation or senior team's level of competition, and expected accompanying staffing structures. This club list was disseminated via a shared online platform (Google Drive) to all members of the research group, with the aim of ensuring all clubs were contacted. Sixty of the responses were from the United Kingdom, resulting in an estimated 50% response rate of potential clubs.

3.2.5 Data Analysis

Survey responses were exported from Lime Survey to Microsoft Excel. This dataset was analysed using IBM SPSS Statistics (version 29, IBM, New York, USA). Like previous research, categorical and multi-choice responses are presented by mean value and standard deviation, and percentage of responses (Weston, 2018; Nosek, et al., 2021). Likert scale responses were presented as integers values alongside the qualitative descriptor associated with the mean response (Hopkins, 2010). Where open short responses were allowed to be submitted within the survey, responses of similar content were amalgamated to present shared participant views, or where suitable, were described verbatim.

3.3 Results

3.3.1 Physical Performance Support

The physical performance department of the surveyed soccer clubs were staffed by multiple practitioners operating across several different roles. The average department consisted of 5 ± 3 practitioners (not including full-time students) working full-time. Figure 1 highlights that most departments included a 'head of performance' (93.7%) and/or 'lead sport scientist' (76.2%), whilst 23 had at least one student within their department. Notably, only around a quarter of performance departments (25.4%) operated with a dedicated data analysis staff member.

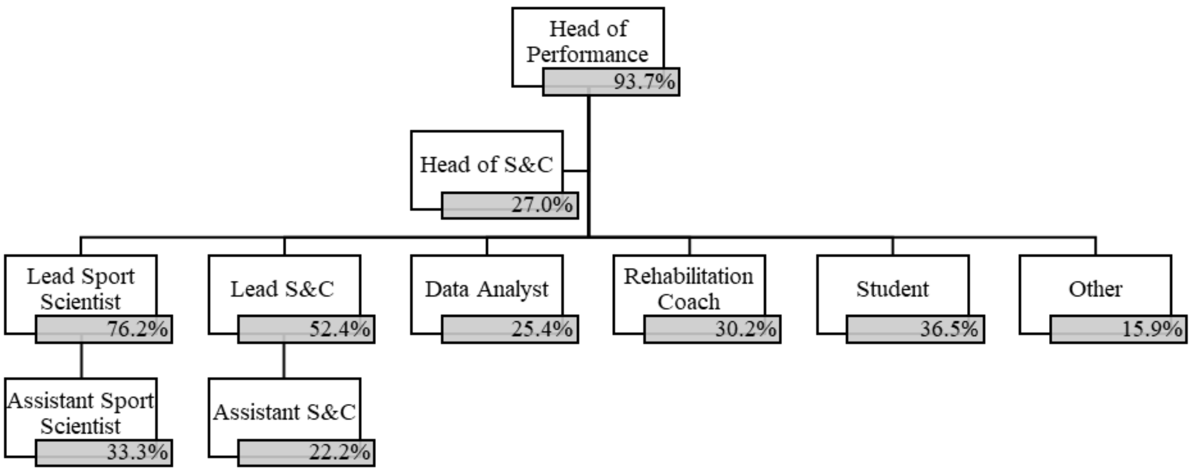


Figure 1: Interpretation of hierarchical structure of physical performance departments and the percentage (%) of soccer clubs surveyed (n = 63) with the listed position filled by at least one full-time practitioner. (S&C = strength and conditioning coach)

3.3.2 Purpose of Physical Performance Monitoring

The two primary purposes of physical performance monitoring were listed as supporting athlete "development", (15 of 43; 34.9%) and "injury prevention" (13 of 43; 30.2%). Most respondents who ranked "development" as their monitoring priority worked within academy age groups (13 of 15; 86.7%). Conversely, most respondents who prioritised "injury prevention" worked with senior clubs (9/13; 69.2%). When questioned if they felt their purpose for monitoring was being achieved through current monitoring practices, three quarters of performance staff were positive it was (30 of 41; 73.2%). Thirty of forty-three (69.8%) practitioners believed return on investment for physical performance data collection was "good" or "high", with six (14.0%) and seven (16.3%) practitioners viewing it as 'average' or 'below average/poor' respectively. Despite many practitioners being satisfied with their monitoring practices, several staff identified there were certain areas where improvements could further improve the return on investment and the impact physical performance data could have. Performance staff noted that 'improving efficiency' and creating more 'impactful insights' would improve the effectiveness within soccer clubs. Eight respondents noted that creating greater staff "buy-in" from non-performance staff would improve the effectiveness in implementing findings discovered through the collection of physical performance data. After determining the purpose of performance monitoring, the survey moved to explore the methods of monitoring used to achieve these desired outcomes.

3.3.3 Physical Performance Data Collection Areas and Frequency

To ascertain the scope of data monitoring within soccer clubs, the collection of individual types of physical performance data was collected. Figure 2 displays the number of departments collecting data in each specific physical performance area. As these performance areas were pre-defined, respondents were permitted to submit 'other' areas of monitoring. Only two respondents utilised this, with both commenting "anthropometrics". With the collection of anthropometric data being related to body composition, these results were included within the pre-defined category. Overall, the results highlighted that the pre-defined areas were suitably expansive and detailed to provide a representation of the possible performance monitoring areas.

All streams of physical performance data were more commonly collected by clubs than not, except for “internal response/recovery”. External load monitoring was the most monitored area by performance departments in professional soccer, with all but one collecting data from this physical performance area.

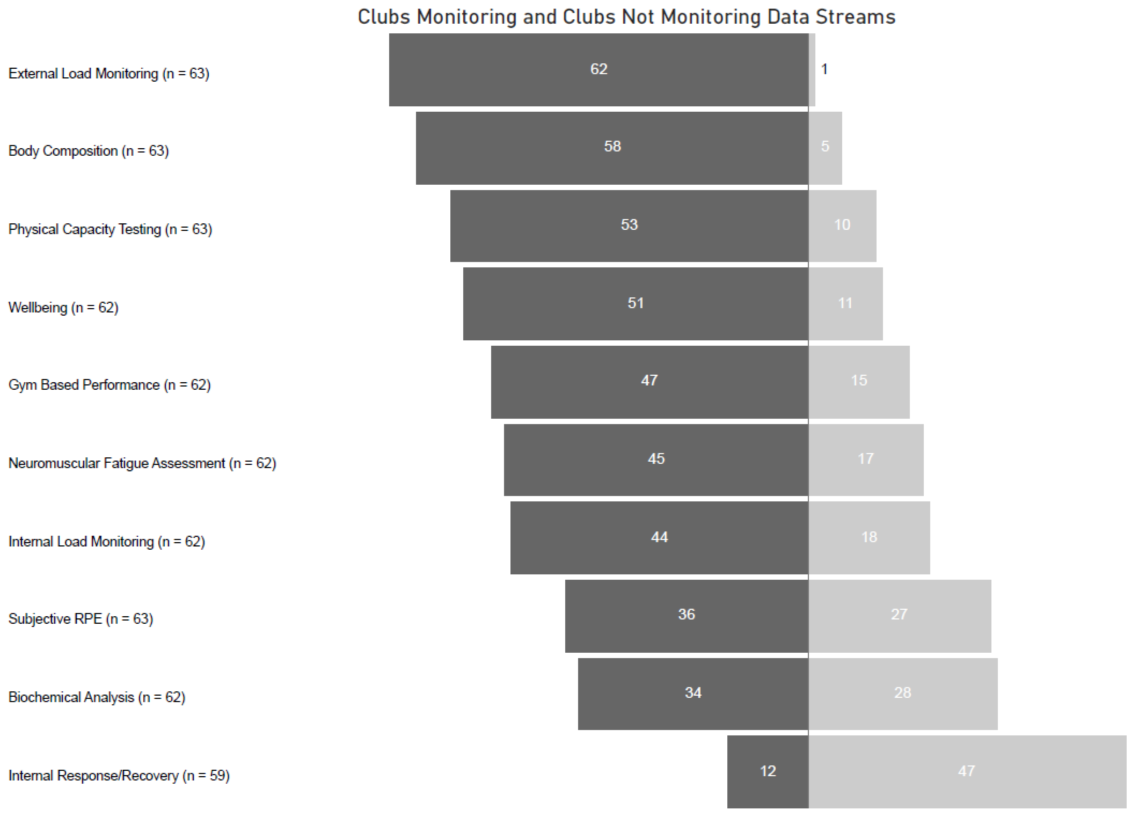


Figure 2: Proportion of clubs monitoring (dark grey) or not monitoring (light grey) individual areas of physical performance data.

The frequency with which this data was collected is highlighted in Table 1. It is evident that data collection occurs regularly within clubs, with seven of the ten performance areas being monitored at least weekly. Data relating to physical loading and readiness to train (wellbeing) are collected on a more frequent basis, with over 88% of clubs collecting these data streams daily.

Table 1: Breakdown of the percentage of frequency with which surveyed clubs collected physical performance data pertaining to the individual listed monitoring areas

	Frequency					
Monitoring Area	Daily	Weekly	Monthly	Quarterly	6-12 Months	On Request
External Load (n = 61)	98.4%	1.6%	0.0%	0.0%	0.0%	0.0%
Internal Load (n = 42)	88.1%	0.0%	4.8%	0.0%	0.0%	7.1%
Subjective Rating of Perceived Exertion (n = 37)	89.2%	0.0%	0.0%	0.0%	0.0%	10.8%
Wellbeing (n = 50)	92.0%	4.0%	0.0%	0.0%	0.0%	4.0%
Neuromuscular Fatigue (n = 41)	9.8%	70.7%	9.8%	7.3%	0.0%	2.4%
Biochemical Analysis (n = 31)	3.2%	54.8%	3.2%	3.2%	12.9%	22.6%
Internal Response (n = 12) (100%)	50.0%	8.3%	8.3%	0.0%	0.0%	33.3%
Physical Capacity Testing (n = 52)	0.0%	1.9%	5.8%	53.8%	28.8%	9.6%
Body Composition (n = 55)	0.0%	9.1%	60.0%	20.0%	7.3%	3.6%
Gym Based Assessment (n = 49)	18.4%	63.3%	0.0%	8.2%	6.1%	4.1%

With both the scope and frequency of monitoring established, practitioners were asked to comment on the quantity of data they collect in comparison to when they began working in elite soccer. Most stated the volume of physical performance data has increased during that time (36 of 40; 90.0%). This was supported by comments liking this increase to “more access to different technologies”. Several practitioners cited GPS and force plates as primary contributors. With data being collected at a high frequency, across many areas, the following section proceeded to establish the systems in place to process this data.

3.3.4 Physical Performance Data Processing and Analysis

To help extract insightful information, clubs may process their collected data using suitable computer software and the application of appropriate analytical methods. Fifty-six respondents completed the survey section related to the method of physical performance data analysis. The majority (96.4%) used ‘standard’ computer software (e.g., Microsoft Excel, Numbers), with thirty-nine (69.6%) using specific data visualisation software (e.g., Microsoft Power Bi, SPSS, Tableau). Forty-four (78.6%) respondents used analysis featured within the software (e.g., Catapult’s Openfield) that was used to collect the data. Twenty-five (44.6%) clubs used an AMS, with five (8.9%) using artificial intelligence (AI) to support their physical performance data analysis. Notably, most respondents (69.6%) used a combination of three or more systems to analyse data. Seventeen (30.4%) practitioners responded that they used four or more systems for data processing. There was also a high level of variance within the most common analytical processes involved in the data processing phase. Of 46 respondent, 25 (54.3%) mentioned ‘acute: chronic ratio’, 33 (71.7%) listed the use of comparison to averages, and 20 (43.5%) reported using the smallest worthwhile change (SWC).

Following the processes used to analyse data, the survey also questioned the efficiency of this analysis. This examined the volume of metrics collected, compared to those used in analysis. This provided an overview of data redundancy involved within the surveyed clubs. Table 2 highlights that every area of physical performance monitoring contained a proportion of data redundancy. External loading presented the most efficient use of collected data. However, within this monitoring area, 15.8% of practitioners still reported they used less than “most” of the data. Biochemical marker analysis was the most inefficient data collection area, with over a third of respondents leaving ‘all’ or ‘most’ of their data unused.

Table 2: Breakdown of the reported collected data used within further processes (e.g., analysis and/or feedback) within surveyed clubs

Metric	None to Very Little	Most Unused	Some Used	Most Used	Almost All to All Used
External Loading (n = 57)	0.0%	1.8%	14.0%	54.4%	29.8%
Internal Loading (n = 39)	7.7%	10.3%	23.1%	41.0%	17.9%
RPE (n = 39)	10.3%	10.3%	15.4%	20.5%	43.6%
Wellbeing (n = 48)	2.1%	6.3%	10.4%	39.6%	41.7%
Neuromuscular Fatigue (n = 44)	11.4%	11.4%	22.7%	34.1%	20.5%
Biochemical Markers (n = 31)	22.6%	12.9%	9.7%	12.9%	41.9%
Internal Response (n = 23)	21.7%	8.7%	26.1%	13.0%	30.4%
Physical Performance (n = 52)	7.7%	1.9%	17.3%	34.6%	38.5%
Body Composition (n = 55)	3.6%	9.1%	12.7%	29.1%	45.5%
Gym Based (n = 42)	7.1%	11.9%	16.7%	38.1%	26.2%

3.3.5 Physical Performance Data Feedback and Use

Data has the capacity for use in supporting decision making within the club. However, for actions to stem from this information, the data must be fed back. This can be internally, to the performance practitioner, or to other stakeholders, such as coaching and medical staff. The most frequent interaction between stakeholders and physical performance data involved staff with a direct influence upon the daily operations of soccer player management. Surveyed departments provided coaching staff (47 of 48 clubs; 97.9%) with daily (87.2%) or weekly (12.8%) updates. This was also the case for updates to medical staff, (45 of 48; 95.7% provided daily or weekly) at 98.0% (48 of 49 clubs). Performance data was also used to inform playing staff (46 of 48; 95.8%). Beyond the immediate stakeholders involved in the player development processes, senior management (40 of 46; 87.0%), analysis (31 of 42; 73.8%), and scouting (20 of 41; 48.8%) staff also received information across the surveyed teams, on a less frequent basis. Encouragingly, Table 3 highlights that most practitioners believed this data was fed back in a timely manner. Table 3 also highlights that physical data was routinely included within frequent collaborative meetings between staff.

Respondents perception of how this feedback was received by these stakeholders presented a mixed finding. Whilst most felt it was "well" received, comments also did refer to the need to create better "buy-in", more "education" of coaches to support understanding, and the need to establish "relationships" with key staff. Eleven (26.2%) respondents referenced this need to increase "education", including the development of their coach's understanding of the metrics currently in use. Six (14.3%) respondents believed the data was not received well, with one respondent stating that "data was wasted…without coaches buy in", due to their prominent role within the club processes. Table 3 also expands to demonstrate the areas in which physical performance data is used within the surveyed teams. This survey section utilised pre-defined areas associated with decision making factors relevant in the player development process.

Table 3: Use of physical performance data in pre-listed decision-making processes within surveyed clubs

Statement	Never	Rarely	Sometimes	Often	Always
Reported to stakeholders in timely manner (n = 48)	4.2%	0.0%	8.3%	35.4%	52.1%
Data used to compare between players (n = 48)	2.1%	4.2%	22.9%	41.7%	29.2%
Data used to determine training content/physical load (n = 48)	2.1%	2.1%	20.8%	54.2%	20.8%
Data used to determine if a player trains (n = 48)	4.2%	22.9%	35.4%	29.2%	8.3%
Data used to determine if a player plays (n = 48)	10.4%	27.1%	45.8%	12.5%	4.2%
Data used to determine physical development objective of player (n = 48)	4.2%	6.3%	8.3%	56.3%	25.0%
Data used in talent identification process (n = 48)	14.6%	25.0%	22.9%	20.8%	16.7%
Occurrence of meetings between sport science and staff regarding physical data (n = 48)	2.1%	4.2%	8.3%	47.9%	37.5%

Data was shown to be used within the training planning process, influencing decision making relating to training content. This was a common finding, with 75.0% of club's using this information "often" or "always". Only 4.2% of clubs "rarely" or "never" used this information. Data was also used, albeit less frequently, to inform upon players' participation within training. However, its use on matchday was less apparent, with only 16.7% of departments regularly using it to assist in squad selection. Use was also seen across other areas of surveyed teams strategy, including the talent selection process and physical performance development planning.

Beyond short-term decisions, respondents noted the presence of data informed research. Internal/external research was completed within 34 of 55 departments (61.8%). Physical performance data was used to support projects, either independently or in collaboration with a university/further education institution. Feedback detailed how this "slow" use of data through collaborations and internal research projects had led to departments adapting both feedback processes, and jump monitoring, in addition to the production of scientific publications. Overall, the results presented a very wide range of data use within performance departments, highlighting immense variability between their approaches to data backed decision making.

3.4 Discussion

This research has explored the purpose, and structures of performance data monitoring, identifying staffing, data collection, processing, feedback, and use, within professional soccer performance departments. Data is collected across many areas of physical performance, utilising a vast array of methods to support the priority objectives of 'athletic development', and 'reducing injury risk'. To support this, performance departments operate with multi-person staffing and monitor many aspects of physical performance. Despite the noted increase in data collected, many departments do not operate with a dedicated data practitioner. Alongside this, clubs utilise multiple methods of data processing and analysis, likely leading to the reported feeling that current data monitoring practices are not "efficient". This inefficiency is also seen by the collection of redundant data, that is not utilised in the analysis and feedback processes may further compound these issues. Despite these concerns, evidence does highlight that many performance departments are supporting decisions including training planning, player availability, and talent identification with physical performance data. Additionally, 73.2% of respondents believed their data monitoring processes assisted them in achieving their aims, with 69.8% reporting a positive return on investment. However, despite the positive use of physical performance data in player development decisions, and the largely positive practitioner feelings, concerns still exist. Many performance departments appear to be functioning at a level of operational unreadiness. This comment is made when considering the lack of specialist data staff, appropriate use of storage and processing systems, evidence of data redundancy, and varied levels of data influencing club decisions. If technological advancements continue, and the volume of handled data continues to grow, this may heighten the stresses placed upon performance departments to efficiently and effectively, collect, analyse, and use physical performance data.

The research highlighted that performance departments are staffed by around five practitioners. This inclusion of multiple performance staff is expected within professional clubs, due to the expansion of supporting staff within soccer clubs (Drust, 2019; Nosek, et al., 2021). However, it is apparent that there is a lack of teams who currently employ a dedicated data specialist. This means the role of monitoring and data analysis is likely combined within other practitioners responsibilities. With performance staff already under stress to effectively manage the physical development of their players, the additional responsibilities involved in effective data monitoring may be detrimental to staffing performance (Malone, et al., 2018). Whilst research has hinted that clubs are beginning to employ data specialists (Newell, et al., 2022); this research has for the first time detailed that only around a quarter of departments have a specific individual tasked with data. This is possibly a result of the unpreparedness, or financial limitations of some clubs to facilitate and appropriately manage the introduction of technology and the concomitant level of data. Research has emphasised the importance of ensuring clubs are suitably ready to embrace technology through the employment of skilled staff and appropriate means of managing data (Rojas-Valverde, et al., 2019; Newell, et al., 2022). These staff should have the skillset to appropriately process and analyse the data to ensure accurate findings are being extracted, and effectively translated to stakeholders to support decisions (Malone, et al., 2020; Nosek, et al., 2021; Newell, et al., 2022)

Despite this lack of data specialists, performance departments were still shown to collect a vast array of physical performance data. The areas of physical monitoring included load monitoring, wellbeing, body composition and physical capacity testing. Previous research has also shown how within these individual areas of performance, multiple technologies and methods of data collection exist (Akenhead & Nassis, 2016). Despite these areas of performance being pre-defined, they were successful in capturing the wide-ranging physical monitoring strands. This identification of areas of monitoring may allow future research to explore in greater detail these individual avenues and their relationships with the key monitoring objectives.

A central finding of this research highlighted the primary objectives for which support is provided through data monitoring. Practitioner responses identified two leading themes: these were to support 'athletic development' and 'injury mitigation'. Interestingly, their focus was influenced by the age group at which the practitioner was working within. Despite a likely shared drive for success and desire to ensure players remain injury free, the overarching goal of academy soccer is not fully aligned with that of senior teams. With academies striving to prepare their players to cope with first team demands (Elferink-Gemser, et al., 2012; Mills, et al., 2012; Raya-Castellano & Uriondo, 2015; Morgans, et al., 2022), their focus is primarily on improving the capacity of their players, a finding reflected in the results. As success in senior soccer may return massive financial reward, and the impact of injury to key players can have a negative influence upon team performance, practitioners within these settings prioritise data to inform upon injury mitigation (Arnason, et al., 2004; Eirale, et al., 2013; Hägglund, et al., 2013; Heidari, et al., 2019). This signifies that data use closely reflects the importance of the user's objectives within their role.

With a clear purpose for data monitoring established, evidence highlighted the frequency with which data is collected. Many performance areas collect information daily. Over 90% of respondents gathered data from external loading and wellbeing every day. With external loading previously demonstrating a high number of available metrics (Akenhead & Nassis, 2016), it is apparent the immense level of data that many practitioners will likely collect across the weeks and months of a season. Adding to this, respondents noted an increase in the overall volume of data. This places great importance upon the data handling systems that exist within clubs to effectively process and analyse such a large quantity of information.

Many departments were shown to lack centralised data management system, rather, operating a multi-system setup, that combines standard computer packages (e.g., excel) with other forms of data processing and visualisation software. Some practitioners reported that in their monitoring setup, at least four systems were in operation to process physical performance data. This finding is supported by previous research, highlighting the most common analytical software to be standard computer packages (Microsoft Excel) (Asimakidis, et al., 2024). Such programmes have inherent limitations when considering the volume and complexity of data that they must handle. Despite increased uptake in more advanced analytical software (e.g., SPSS and coding-based platforms), the lack of specialist support staff may delay such widespread advancement in the area. Ultimately, for data to be impactful, appropriate metrics should be collected and analysed appropriately. With multiple systems currently in operation, many very basic, and data housed in separate storage systems, processed data may not have the ability to produce accurate, informative insights (Bourdon, et al., 2017; Williams, et al., 2017; Weaving, et al., 2019; Ryan, et al., 2021).

Regarding the methods of analysis conducted upon collected material, comparison to average results was the most common method listed. This was followed by ACWR and application of the smallest worthwhile change (SWC). It is important practitioners understand these methods of analysis and statistical approaches, due to the limitations that exist. Such methods may not consider the "individual" aspects if applying analysis across a 'team' setting (Ward, et al., 2018). Additionally, the application of these methods, whilst done with good intentions, could result in false confidence regarding findings. Despite a high proportion of practitioners comparing results to previous scores, very few highlighted any analysis accounting for measurement error. As such, incorrect insights could be drawn from the findings (Asimakidis, et al., 2024). Furthermore, the use of the ACWR has previously been challenged in research, with findings suggesting "inappropriate recommendations" may be concluded (Impellizzeri, et al., 2020). These findings are in line with recent research examining the use of physical testing data only (Asimakidis, et al., 2024). The authors reported a "lack of consensus" existing across practitioners. This outcome strongly agrees with the results produced by this present study. Whilst all analytical methods likely contain weaknesses, the variety of analytical processes employed, combined with the lack of data specialists warrant caution.

Adding to the challenge of efficient data monitoring and processing is evidence that a high proportion of departments are collecting excess data. External loading and wellbeing data were the most efficient data monitoring areas, with practitioners reporting most of the collected data was used. However, internal response (fatigue monitoring) and biochemical markers were the least efficient, with over 20% of practitioners using "none to very little" data. Such inefficiency has the potential to waste practitioner time through needless data collection, in addition to club finances. As such, it is important that clubs should assess their use of collected data. It may be that this inefficiency is because of staff shortage and/or the clubs available data processing systems. As a result, data may not be able to be used in an efficient manner.

Research also examined the way physical performance data transitioned from analysis, to feedback, and ultimately use. Positively, this information appeared to be presented in a timely manner during regular stakeholder discussions. This allows for decisions to be made within an effective and efficient timescale. Information was routinely fed back to coaching, medical and playing staff. This information was also provided on a frequent basis, routinely daily or weekly. Whilst providing feedback is important, it is vital that it communicates the intended message (Buchheit, 2017; Lacome, et al., 2018). Concerns regarding this feedback process and its impact upon use were raised by respondents. They believed that education was required to support this process, along with the development of relationships with key stakeholders, to assist in buy-in. This intimates that data use therefore may be being stifled by a lack of understanding by stakeholders, and through appropriate education through improved feedback and translation, use of the data may improve.

Positively, data was still seen to influence some operational decisions, with physical performance data regularly influencing training content. Results showed that 95.8% of practitioners felt that physical performance data was "sometimes" to "always" used in the planning of training. This agrees with research highlighting the potential to manipulate the training load players are exposed to, based upon the desired physiological adaptations, proximity to a match, and players' readiness to train status (Kelly, et al., 2020; Hostrup & Bangsbo, 2022). Performance information was also used to profile players, through comparison, talent identification and the determination of training targets. This could be used to discriminate between high- and low-level performers, as seen when comparing the physical capacity and playing level of players (Wisloff, et al., 1998; Impellizzeri, et al., 2008; Taylor, et al., 2022). Additionally, targeted training interventions to improve specifically identified areas can be supported with this data (Paul & Nassis, 2015; Taylor, et al., 2022).

However, concerns do exist in relation to the effectiveness of physical performance data across other decision-making areas. Data does not appear to have permeated the ability to fully determine players' training and match-day involvement. 62.5% of clubs "never" to "sometimes" use data to determine training availability, with 83.3% of clubs having "never" to "sometimes" used data to determine players' match availability. This suggests that despite the extensive volume of data collected, there does not exist extensive use of physical performance information to inform upon players availability. This may be an area requiring development, as research has highlighted the increase in injury risk during periods of fixture congestion (Dupont, et al., 2010; Dellal, et al., 2015; Silva, et al., 2018). Whilst practitioners are likely to be reluctant to suggest players are removed from soccer matches/training, if data suggests this is appropriate, there must be trust in the use of it. With one of the key identified objectives of data monitoring being injury mitigation, it is worthwhile investigating the impact data can have upon manipulation of players' physical loading. Importantly, should practitioners make such suggestions, it is paramount that any information is supplied to practitioners in a clear and effective manner. If not, this could prevent future action being taken. Encouragingly however, the present use of data resulted in most practitioners believing they achieved their monitoring objectives and received a good return on investment for monitoring practices. However, if concerns are not addressed, it is possible that these present views may change.

Together, this research emphasises the need for clubs to invest beyond technology alone and support decisions through the employment of data specialists and appropriate data management systems. One common method of providing detailed insights related to the collected information involves the use of formal in-house or educational institute supported research. This “slow” research can yield detailed insights that can ultimately influence practice within clubs (Coutts, 2016; Coutts, 2017; Malone, et al., 2019), such as practices “jump monitoring” and “feedback methods”, as noted by respondents. This may be supported through the integration of students within performance departments to combine research and practice, a setup observed in under half of the surveyed departments. Promisingly, over half of the performance departments were currently engaged in further research, either internally or in collaboration with educational institutions.

3.5 Conclusion

Physical performance monitoring in soccer is an extensive operation, detailing multiple facets of athlete’s physical status. This data is collected to achieve operational aims, associated to the level that the club is operating at (academy or professional). These aims are physical development and injury mitigation.

Despite most surveyed departments not operating with a specialist data practitioner, teams collect data across multiple areas of physical performance. Much of this information is also collected on a frequent basis, with some areas of physical performance monitoring, such as load monitoring and wellbeing, being collected daily. However, research showed that many departments lack appropriate methods of data processing for such a volume of information. Many practitioners reported that they use multiple data storage and processing systems, with most lacking a centralised data hub. This likely resulted in the "lack of efficiency" stated by some practitioners. This was also evidenced by the collection of redundant data. Together, this could all exacerbate the stress/strain faced by many performance practitioners (Malone, et al., 2018).

Concerns were also raised regarding how stakeholder's perceived the data they were provided. Respondents noted that there was a "lack of understanding" and the need to develop more "buy-in" from coaches. Despite this, data use within the clubs was evident. Practitioners evidenced positive use in the planning of physical development and training sessions. Furthermore, at present, practitioners believe there are achieving a good return for investment, along with current data monitoring assisting them in achieving their objectives.

Nonetheless, data monitoring practices and use within most performance departments appears to not be operating at its full potential, with many procedures being inefficient. Where information is collected without impact, finances will be wasted, unnecessary stresses placed upon practitioners, and the potential for player development to be detrimentally impacted. It is therefore important to explore current data processes to identify areas where improvements can be made.

PHASE 2 – DATA USE WITHIN AN ELITE SOCCER CLUB

CHAPTER 4:

A CASE STUDY: EXPLORING THE PROCESSES THAT DRIVE PERFORMANCE DATA COLLECTION, PROCESSING, AND USE TO SUPPORT PHYSICAL DEVELOPMENT WITHIN AN ELITE SOCCER ACADEMY

4.1 Introduction

Results from Chapter 3 have highlighted the following key aspects.

- Monitoring in elite soccer is an extensive operation, harvesting data from multiple data channels, resulting in a wealth of information
- Limitations to the effective use of this data include data redundancy (where data is collected but not used), inefficient data processing systems, and the unsuccessful translation of findings to key stakeholders

The initial study has explored the structure of physical performance monitoring in professional soccer. This identified that professional soccer clubs operate with a multi-person backroom team, who's primary purpose is to support soccer players' development and preparation for competition (Otte, et al., 2020; Otte, et al., 2020; Balsom, et al., 2022). These physical performance staff collate both objective and subjective data to support decision making, pertinent to their role. It has been established that the primary purpose of physical data and support provided by these practitioners is targeted towards the development of physical attributes and the mitigation of injury risk. The collected information can be used to directly influence strategies to achieve these goals, or, be used in collaboration with other stakeholders, such as the coaching staff (Nosek, et al., 2021; Taylor, et al., 2022). This study will explore in detail these performance monitoring processes, and how data impacts club-based decisions.

Physical performance data can be communicated between key stakeholders to successfully deliver in a unified approach, to achieve a common goal (Reid, et al., 2004; Ryan, et al., 2021). **Chapter 3** evidenced that inclusive in this stakeholder network are coaching, medical, performance/sport science, analysis, and operational staff. The role of performance/sport science staff in this process is to provide information relating to the physical profile of players, to support the players' physical preparation for competition (Brink, et al., 2018). These practitioners exploit a multitude of methods and technologies, across multiple contact points, to build a detailed picture of their players' physical status (Drust, 2019). Despite research recognising both the value and issues related to such data collection and its communication between stakeholders, research is limited (Malone, et al., 2020; Nosek, et al., 2021; Newell, et al., 2022). Thus far, no research has examined club-based practices of data monitoring. To better understand data monitoring, it is important to identify the processes involving physical performance data that may yield resultant actions that impacts the player monitoring and development process within clubs.

Of the existing literature, research has begun to explore the possibilities of physical data supporting decision making within soccer on a general level. One area recognised as benefiting from the collaborative data sharing approach is the design of training sessions, a finding highlighted in previous research (Nosek, et al., 2021) and within **Chapter 3**. Whilst it is documented that training content is primarily determined by coaching staff, performance staff were viewed as having some influence upon this decision (Nosek, et al., 2021). Practitioners may use their collected data to advise upon the manipulation of planned physical training loads. This is done to reduce the likelihood of overtraining or underloading players. Inappropriate loading has the potential to increase injury risk and/or result in the detraining of physical attributes (Mohr, et al., 2005; Nedlec, et al., 2012; Malone, et al., 2015; Anderson, et al., 2016; Hader, et al., 2019; FIFPRO, 2022). Research has also identified that exposure to certain physical stimuli may improve physical capacities and/or mitigate injury risk (McMillan, et al., 2005; Malone, et al., 2017).

Through the collection of appropriate data, collaborative decisions in the determination of training requirements can be made (Weston, 2018; Balsom, et al., 2022).

Should the evidence provided by the performance department raise greater concerns around the players ability to tolerate physical load, a more impactful approach can be taken, such as removal of the player from the session, or alteration to physical loading (Bourdon, et al., 2017; Heidari, et al., 2019). The monitoring of players' readiness levels can be conducted to provide this insight into the recovery status of players'. This provides an awareness into the players physical condition, and whether recovery has been sufficient to allow for regeneration of physical qualities (Kellmann, 2010; Heidari, et al., 2019). Such information can be used to reduce the likelihood of players entering training/match play in a physically compromised state, negatively impacting performance, and increasing risk of injury (Noon, et al., 2015). This information is imperative with the likely increase in physical demands, placed upon players across the season.

Beyond short term decision making, another identified information stream involves the physical 'testing' of an individual's physical capacities. This provides practitioners with a snapshot of an individual or team's physical performance characteristics. This may allow for evidence backed planning of a targeted intervention and training programme, in addition to being able to reflect upon its effectiveness. The development of these physical capacities can support improved performance and injury mitigation (Helgerud, et al., 2001; Wisløff, et al., 2004; Falch, et al., 2019; Taylor, et al., 2022).

Despite the potential benefits of such informed decision making based on collected physical performance data, concerns have been raised surrounding the translation of this information into informative practice involved in the player development process (Nosek, et al., 2021). Shared information should be able to inform decision making within the club, therefore be easily understood by relevant stakeholders (Bourdon, et al., 2017). This information should also be provided to the necessary stakeholders in an efficient manner to ensure quick actionable decisions. It has been emphasised that the relationships between stakeholders is vital to ensure a flow of information through teams (Buchheit, 2017; Ward, et al., 2019). This was also highlighted within **Chapter 3**, where improvements between staff relationships, and further education of coaching staff, may help support “buy-in” to data use. This concern regarding feedback and communication between staff has been referenced in relation to injury burden, and player availability. When communication was poor, injury risk and player availability fell, findings likely impacting the success of soccer teams (Eirale, et al., 2013; Ekstrand, et al., 2019). Poor internal communication was also previously suggested as an extrinsic risk factor in relation to injury prevention (McCall, et al., 2016). Where supporting information is shared and communicated clearly between staff, adaptive responses to players’ physical workload could be implemented, reducing injury risk (McCall, et al., 2016).

As identified, physical performance data covers many aspects of the player development process. Whilst **Chapter 3** and some existing literature has presented an overview of the monitoring process, a much more detailed, single club perspective is now required. This is needed to explore the process driven view of the use and support physical performance data provides within a soccer club. Therefore, this study aims to identify the physical performance data collection, analysis, and feedback processes within a soccer club. This will also examine the stakeholders involved within these processes. Furthermore, it aims to explore where this performance data supports decision making to ultimately act within a soccer club.

4.2 Methods

4.2.1 Study Outline

To investigate the aims, a two-phase study design was created to explore the current physical performance monitoring practices of a full-time professional senior academy soccer team's (U21). A five-week in-season observational study was used to establish the data that was being collected, analysed, and fed back within the club. It also explored how this information supported staff, and subsequent decision making and use. Following this, interviews with the coaching and medical staff were conducted to provide a detailed subjective opinion on how these staff perceived their use of the physical performance data. Ethical approval for the study was granted by University of Birmingham's ethics committee (ERN_2022-0259).

4.2.2 Participants

The observational analysis included both players and staff from the team, competing within the fifth tier of Scottish football. The backroom staff consisted of a head coach, assistant coach, goalkeeping (GK) coach, a physiotherapist, a doctor, two sport scientists, and two performance analysts. Five of the members of staff involved in the observation analysis were also included within the interviews (Table 4). Four were members of the coaching staff and one a member of the medical department. The coaching staff all held a UEFA A licence (or UEFA A Goalkeeping licence) and had experience working for at least two clubs. The physiotherapist had worked within professional soccer for 20 years, working with several managerial regimes and performance support staff. These staff were selected due to the immediacy of their role in the player development process. As both the team's sports scientists were involved with the data collection (and reliability study), these staff members were not included in the interviews.

Table 4: Interview participant information documenting their position within the club, years involved in professional soccer, highest associated qualification in addition to relevant experience. Professional development phase, PDP)

Reference Name	Club Role	Years In Professional Soccer	Highest Qualification	Relevant Experience
Coach A	Head PDP Coach	27	UEFA A Licence	Ex-professional player
Coach B	Assistant PDP Coach	20	UEFA A Licence	Ex-professional player
Coach C	Lead PDP Coach	12	UEFA A Licence	PhD Candidate in Coaching
GK Coach A	Head of Academy Goalkeeping	27	UEFA A Goalkeeping Licence	Ex-professional player
Physio A	Lead Academy Physiotherapist	20	HCPC Registered	

The players (n = 23; 19.3 ± 1.6 years old) were only used within the observational analysis, where they were part of observed subject group, performing their normal daily tasks. Players were not interviewed, as this study focused upon the data used to support the development of players, in particular, decisions made for players, by staff.

4.2.3 Observational Analysis

The observational analysis was 'participant observation' in nature. This recording method presents "actual" practice insights (Busetto, Wick, & Gumbinger, 2020). This meant normal daily practice was continued whilst using the observation was conducted. All participants involved in the study were asked to conduct their roles as normal, limiting any change towards normal usage of physical performance data. The observer was the primary researcher, and a member of the team's physical performance staff. As the observer was an embedded staff member, this meant there was no disruption to normal practice (e.g., presence of external researchers). Whilst this hopefully resulted in a sense of normality to observed practice, it is possible that due to the ongoing study, staffs behaviour could have been altered (Gratton & Jones, 2010).

The observational analysis form (see Appendix 3) was created for this specific study to allow a sport science practitioner to record interactions with physical performance data within the club. This form set out key areas of focus for observation, determined using findings from **Chapter 3**. Data supporting the commonality of professional clubs collecting data in these performance areas is presented within Table 5. These areas included player wellbeing, a player submitted subjective marker used to assess player readiness, frequently collected within professional soccer clubs. Physical loading, a common and frequently collected data stream, was presented split into external and internal values in case of observation of just one area. Gym based load monitoring was used to record physical activity output within the gym environment. Finally, physical capacity testing, frequently used within professional soccer clubs, was used for any assessment of a player's physical capacities. The use of pre-defined areas for observation supports the efficiency of data collection (Gratton & Jones, 2010).

*Table 5: Key areas of physical performance monitoring, identified from the survey in **Chapter 3**, based upon the most monitored areas of physical performance*

Key Physical Performance Monitoring Areas of Observation	Percentage of clubs monitoring performance area (**Chapter 3**)
Player Wellbeing	82.3%
External load monitoring	98.4%
Internal load monitoring	71.0%
Gym based load monitoring	75.8%
Physical capacity testing	82.5%

The observational form was split into two forms per day. The first form collected the occurrence of data events. This documented if physical performance data was collected, analysed, and fed back. Collection involved the process of utilising a monitoring method or technology to gather new data. Analysis involved observing the data through the application of statistical methods to provide a more detailed insight, or the use of practitioner experience and judgement to extract findings. Feedback was the process of providing information to stakeholders, through multiple mediums including verbal discussion, and computer-generated reports. This process allowed for the incidence of events to be calculated across the observation period. The second form allowed for detailed documentation of the physical performance data events. This provided the observer the opportunity to add information, beyond recording the occurrence of an event. Such contextual information that was added included the timing of the observation, to highlight data interactions within planning meetings, during the session, or post-training. It also extended to the staff involved in the observed data use, and the outcome that any performance data supported decision yielded (e.g., a change of session targets, based upon a discussion related to physical loading information with staff). These observation forms also allowed for the investigation of physical performance data redundancy. This is where data is seen to be collected but then does not continue support any future events (i.e., analysis/feedback).

A weekly summation sheet was also completed to document the weeks total instances of events where the data use extended beyond collection and analysis. This included the occurrence of discussions, enquiries relating to data, feedback of information to any stakeholders, and errors reported within the data collection process. This provided a summary of events from the observed week. This served to aid the efficiency of post-observation data processing.

4.2.4 Observational Analysis Period

Observational data was collected in-season over five weeks, to provide an overview of the physical performance data practices within a full-time, professional senior academy soccer club. This resulted in twenty-five days of observational analysis, with days off excluded. The breakdown of these days included six matchdays, one MD+1, five MD-1 (1 = MD+2/-1), three MD-2 (1 = MD+2/-2), two MD-3, one MD-4 and one MD-6. The MD+1 session was an off-feet recovery day, with players completing gym-based work and recovery modalities only.

4.2.5 Observational Analysis Robustness

As this observational analysis presented a novel method of data collection, efforts to increase reliability and validity were made. An initial trial was conducted, whereby the primary observer became familiar with the observation form. This allowed for amendments to the observation form. Following this, a second trial period of data collection was conducted, whereby two practitioners, working with the same team, completed the observational analysis independently. Two 'practice' days were used to familiarise the second observer with the form.

The first practitioner was the primary researcher, and team's lead physical performance coach. The second practitioner was a qualified performance coach, with over 20-years' experience in high-level soccer. They also served as the team's physical performance coach and lead data analyst. This interobserver reliability analysis was conducted by both observers over four days, utilising the first observation form, documenting the occurrence of events. The analysis of this looked at whether data was collected, analysed, and feedback, across the eight physical performance areas. Of 96 possible yes/no occurrences across the four days, there was agreement on 89 (92.7%) of the data events. Due to the different performance related roles conducted by the observers within the team, failing to register all events was possible and expected. However, the agreement analysis highlighted that most events were still observed by both. Due to only two observers, further reliability analysis of this data would not be credible.

The final observational analysis was completed by the primary researcher, who was experienced in the professional soccer environment, having five years of experience working with several clubs, operating a wide-range of monitoring systems and processes, in addition to previous research roles necessitating accurate data collection. Collected observations were tallied and presented as a frequency value, using integer or percentage value.

4.2.6 Interview Overview

The use of interviews within the study presented an opportunity to expand upon the contextual factors, and coach understanding as to why data was/wasn't used. Interviews allow for the collection of a detailed subjective perspective of the "how" and "why" of physical performance data usage by stakeholders within the observed club (Gratton & Jones, 2010). This process was not completed to supersede the observational data, rather compliment the collected information, and allow greater detail to be added. This was completed to assist in the discussion of observations.

4.2.7 Interview Design

The interview template (see Appendix 4) was created exclusively for this research project. The interview was semi-structured, consisting of a set question list, with the ability for further non-prescribed questions to be asked based upon participant answers and/or discussion content (Ayres, 2008). The question list consisted of fourteen questions across four sections. The first section (two questions) featured ‘establishing’ questions to introduce the interviewee to the interview environment and encourage open discussion (Gratton & Jones, 2010). The following section, ‘introduction to physical performance in soccer’ (two questions), established the participants views on physical performance and its relation to soccer. This allowed for a basic understanding of their physical performance knowledge to be gained by the interviewer. Following this, an ‘introduction to data’ (three questions) section was presented, whereby questions relating to their use and interaction with data in their current role were initiated. The final section, ‘physical performance data in soccer’ (seven questions), specifically detailed the subject’s interaction, involvement and opinion surrounding physical performance data in their role. The interview ended with the opportunity for any additional points related to the discussion to be raised that had not already been presented.

4.2.8 Interview Process, Transcription, and Analysis

All interviews took place in a well-lit and ventilated room where only the interviewer and interviewee were present, to establish a comfortable and private discussion area (Gratton & Jones, 2010). Interviews lasted between 20 and 45 minutes. Interviews were audio recorded (Zoom, USA) and transcribed post-interview (Rev, USA). The audio recording was used by the researcher to amend transcription errors, through full playbacks. Following this, the transcription was studied by the author, with key-points highlighted and extracted into a separate word processing document (Word, Microsoft, Washington USA) from each interview to support results and discussion. All participants were offered the final transcription of their interview to ensure accuracy of transcription and were also informed of a seven-day period post interview to withdraw their submission, without reason being required. Prior to commencement of the interviews, two trial interviews were conducted with a member of sport science staff and a member of coaching staff to gauge the responses and develop interview proficiency and professionalism.

4.3 Results

4.3.1 Observational Analysis

The observational analysis aimed to develop an understanding of the processes that drive the use of data within a professional soccer academy team. This identified (a) the areas of physical performance monitoring and (b) the frequency of this data collection, that (c) fed into key processes to support decision making. Overall, four key areas of performance monitoring and associated data sources were identified, presented within Table 6.

Table 6: Summary table documenting the proposed four key monitoring areas within the observed club, in addition to the key sources of physical performance data.

Performance Monitoring Area	Session Planning	Physical Loading	Physical Testing	Gym-Based Monitoring
Primary Data Sources	Wellbeing Data	Physical Loading Data	Body Composition	Loading and Repetition Data
	Physical Loading Data	Live Physical Loading	Physical Capacity Tests	Velocity Based Training Device

4.3.2 Data Collection

Together, 146 different metrics were observed to be collected (Figure 3) across the four key areas of performance monitoring (highlighted dark red). Physical loading produced 51 metrics, per player, per monitoring event (e.g., single training session/match). Of these 51 metrics, five were used for live physical load monitoring. Wellbeing data accounted for five metrics per player, per submission. Physical capacity testing (71) and body composition (16) made up the 87-testing metrics. Finally, gym-based monitoring provided three metrics, across both load monitoring and live power tracking. Figure 3 provides a visual interpretation of this data collection and the associated data volume.

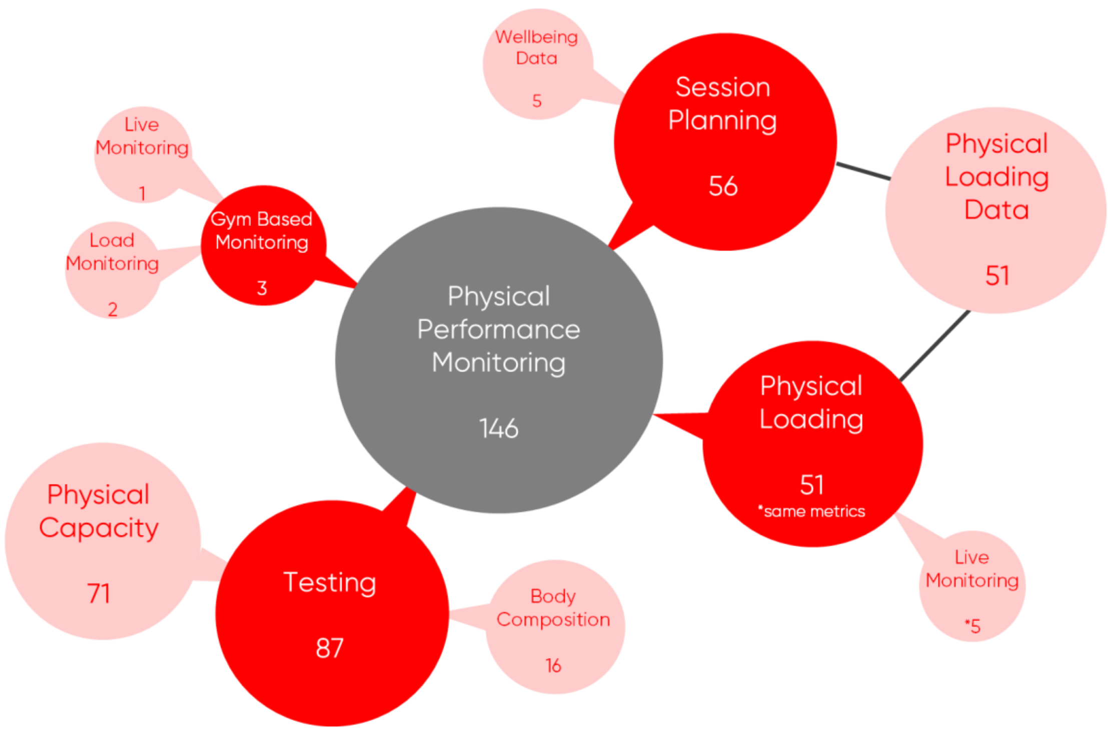


Figure 3: Interpretation of the data collection and use areas, inclusive of metric count, for all observed instances of physical performance data activity across the observed period. Groupings of data is used to highlight the main physical performance areas being monitored. Monitoring areas are highlighted in dark red, with data collection methods highlighted in pink.

4.3.2.1 Data Collection Frequency

With the club-based performance monitoring landscape established, analysis also allowed for identification of collection patterns and frequency of the monitoring areas. Figure 4 presents an overview of this data collection across the observational period. The green box indicates the data was collected and white boxes indicate it was not collected. Grey boxes represent days where specific data types were not monitored, due to the data categorisation implemented. For example, training data was not collected on a match and vice versa. (One exception occurred on Day 1, where a pitch-based rehabilitation session used live monitoring to assess the velocity of a player returning from injury. This resulted in training data being collected on a match day).

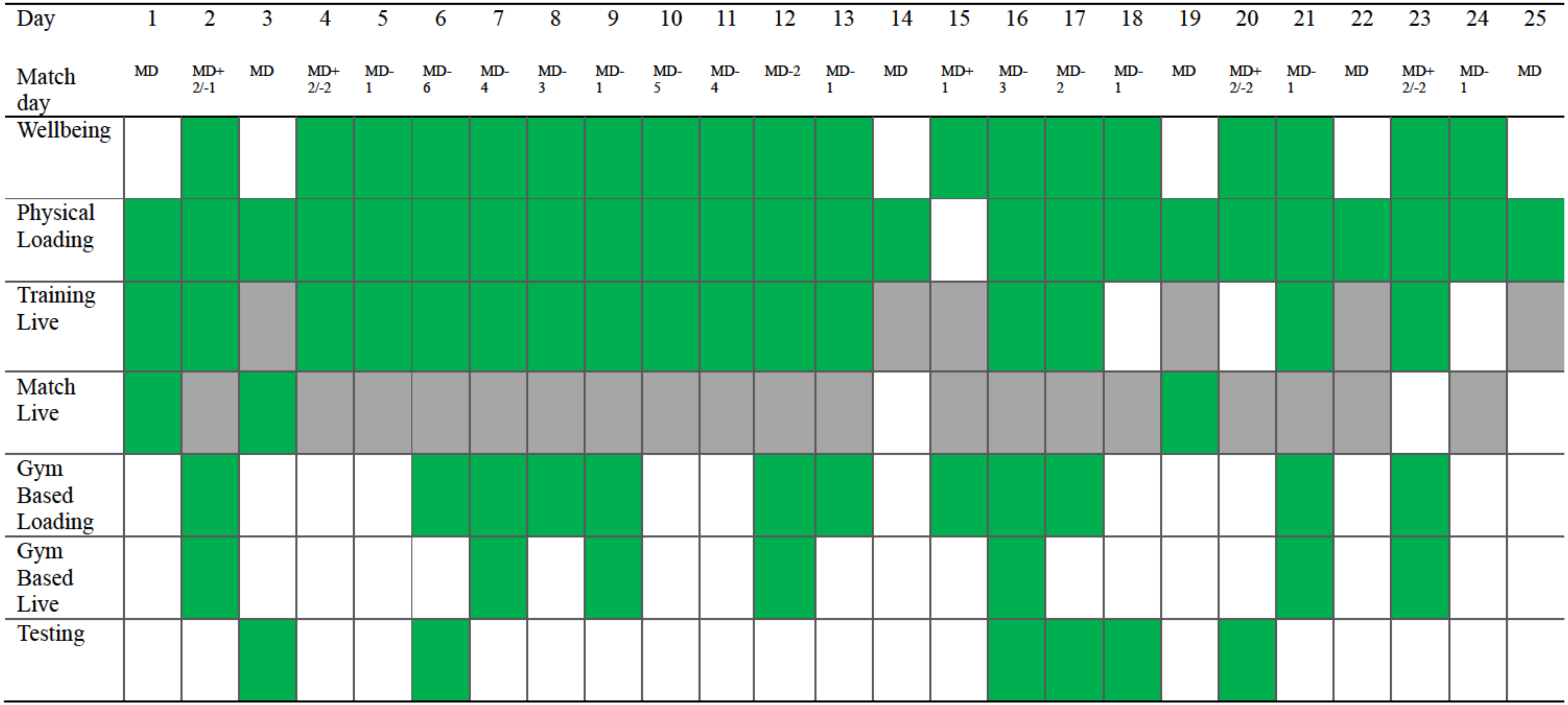


Figure 4: Summary of data collection occurrences (green) for all monitored areas across the observation period. Grey indicates that the data type could not be collected on that specific match day (MD) type (e.g., training data was not collected on a match day and vice versa).

To support the process of session planning, wellbeing data was collected every day (n = 19), except for MDs. To support the planning and load monitoring, physical loading data, including internal and external, was collected during all pitch-based activities, throughout the observed period. Only the recovery day (MD+1), where no on-field activity took place was physical loading not collected. The use of live technology to collect physical load data was also shown to occur regularly. This use of tablet technology allows for real-time data to be observed during a pitch-based activity. This was used for every session between three and six days before a match, with a reduction in use towards matchday. Live monitoring was observed to be used within three of the six matches.

During the observation period, physical performance testing was conducted on an ad-hoc basis. These tests examined multiple facets of physical qualities, including strength, power, speed, and fitness. The observed period included one occasion of physical strength testing using portable strength testing equipment (Nordbord & Forceframe, VALD). This was observed on a MD+2/-2 session. Additionally, body composition, assessed by skinfold callipers, was conducted upon all squad players across a four-day period. One instance of physical performance testing data collected on a matchday was completed by a player not involved with the match squad.

Performance data was also collected during gym-based sessions. This involved collecting individual's loads and repetitions for their completed exercises. Players recorded their loads in a customised digital worksheet (Excel, Microsoft, Washington, USA) on twelve of nineteen gym-based sessions, primarily during strength focused sessions. Additionally, live data collection was conducted utilising live a velocity-based training (VBT) device (Gym Aware, Braddon, Australia). This provided players with instantaneous data relating to the power of their gym-based actions.

4.3.2.3 Data Processing, Feedback, and Use

The observational analysis initially allowed for the understanding of where data collection occurred, and where this data fed into decision making. This information supported the grouping of information to better understand the data processes, presented in Figure 3. The observation also allowed for the documentation of how this data was then used, post-collection, within its specific monitoring area. By detailing the processes of data flow from collection to use, areas of concern/inefficiencies could be identified to support the development of the overall monitoring process.

Planning

Wellbeing data, used to support the planning process, was analysed by the club's performance practitioner prior to the pre-training meetings. This analysis highlight players who had raised wellbeing concerns, such as low scoring values in comparison to their normative values. These findings were then shared within the pre-training meetings. These meetings were attended by coaching, performance, and medical staff, associated with the observed team. These meetings took place on every pitch-based training day (n = 18). No pre-session meetings were observed on the match days. Despite wellbeing data being collected on the MD+1 recovery session no meeting occurred, and the data was not used. This was because no physical loading was planned for that day, with all players completing recovery modalities.

Information presented during these planning meetings was used to support decision making related to player's availability to train, and training content/physical loading. Contextual information, collected by the second observation form, documented the outcomes of planning decisions supported by this data. Player wellbeing data discussed during planning meetings led to seven instances (38.9%; seven of eighteen meetings) of further discussion between stakeholders (coaching, medical, and performance staff). Five of these discussions led to action being taken. This resulted in a total of 27.8% (five of eighteen) sessions having players modified from the 'normal' session plan. These modifications ranged in outcome. Removal of players due to illness and low wellbeing scores occurred twice. There was one observation of a reduction of the whole squads planned physical loading due to several reports of higher-than-normal lower body soreness. There were also two occasions where there was a slight planned reduction in a players involvement in the session to manage the physical demand placed on them. Only on one occasion was physical loading from a previous sessions discussed during the planning meeting and used to support a decision around the need to act. The increases in expected physical loading during the previous match led to a decision to decrease the planned physical loading of that days training session (MD+2/-1 training session). As no post-match discussion took place, this planning meeting presented the first opportunity for this information to be verbally discussed between staff.

<u>Physical Loading</u>

Physical loading was collected during both training and match play. The most immediate form of loading data was live monitoring. This data was analysed visually by the team's performance coach on pitch. This method of collection allowed for instantaneous feedback and the ability to make decisions on-field. The live collected metrics were the same as those collected for the entire physical loading. However, only five were observed to be used. These five loading data points used were the most discussed with staff when planning the training sessions, hence their use on field to track physical loading. The live monitoring focused on total distance (m), high speed running (distance > 5.5 $m.sec^{-1}$), sprint distance (distance >7.0 m.sec^{-1}), maximal velocity (m.sec^{-1}), and red zone minutes (time >90% max heart rate).

Live monitoring was used to inform physical outputs and decision making on four occasions. One event occurred during a training session (MD-2), providing feedback regarding the players percentage of maximal speed attained. This was used to ensure all players recorded a near maximal velocity sprint effort. The exposure to near maximal sprint speed was part of the observed club's physical training philosophy. Live monitoring was also used on a MD (Figure 5, day 1) with live data being used by a physiotherapist completing a rehabilitation session with a player. Due to the injury type, the player's speed was required to be closely observed and therefore live monitoring was used to provide feedback on in-session progression. On matchdays, the live monitoring was used twice to provide additional information to support the prescription of appropriate post-match running requirements of substituted and non-involved players. This decision was made by the teams physical performance coach only.

Collected physical loading, regardless of whether it was monitored live, was also analysed post-training. This was completed using the club's processing systems and internal analysis protocols. This information was regularly fed back as part of a digital generated report. Physical loading data was provided to stakeholders (coaching, playing, medical, and performance staff) following fifteen of the training sessions (83.3%), via this digital report (generated using PowerBi (Microsoft, Washington, USA)). This report was also supported by post-training meetings. In addition to the single use of physical loading data to support pre-training planning, one occasion of post-training loading feedback was observed. Figure 5 (day 16) highlights the event where physical outputs from a training session resulted in a recommendation by physical performance staff to coaches to reduce the following days planned training load (a MD-2 training session). This decision was made during a post-training meeting, following the performance coach highlighting the analysed data. Following all matches (n = 6), physical loading data was fed back to all stakeholders via a digital report. This was generated using Microsoft excel and delivered using an online messaging application (WhatsApp, California, USA). These reports were not observed to provide any follow-up response, rather present a summary of activity only.

Testing

Data gathered from physical testing was shown to be fed back on eight occasions. This information was used twice to provide feedback to coaching and playing staff during player review meetings. These discussions were used to determine developmental targets and influence the creation of physical development programmes. Two informal discussions were also recorded between performance staff and players to provide feedback on physical performance based on collected metrics. These discussions provide players with an update on progress and allow for a review of their current developmental programme. Finally, during the observation period, a structured physical performance staff meeting (MD-1) was recorded to reflect upon physical performance data, including testing, and scheduling was presented to provide a strategy and player progress update. This was used to create departmental and player specific physical performance targets ahead of the next review.

Three occasions of data being fed back with no influence upon any observed action were also recorded. This related to body composition assessments where players were shown an updated and comparative skinfold and anthropometric profile. Whilst this feedback may have prompted a change in players' dietary approach, no action was observed.

Gym-Based Monitoring

Monitoring in the gym consisted of both live bar tracking (VBT), in addition to the recording of players' individual lift loads and repetitions completed. Live monitoring of players' physical lifts was primarily conducted during power sessions, occurring mostly on MD-1, in addition to MD-2 to MD-4 sessions based upon the fixture schedule. This feedback was used to attempt to elicit increased effort.

As the observation did not monitor the impact of the live monitoring feedback to changes in players' performance it was not possible to assess whether the data produced a resultant action. Had performance pre- and post-feedback been gathered, or subjective feedback, the impact of the monitoring could have been assessed. Likewise, the data collected regarding players' total loading and repetitions within sessions was not used within the observed period. Rather, this information was stored for use in the strength and power programming of their next training phase. As this did not occur during the observed period, an outcome was not recorded. Again, this limited the overall assessment of action taken for gym-based monitoring.

Physical Performance Data Process Overview

An overview of these data processes is presented in Figure 5. This highlights the trend of these processes, showing both feedback and data use. This also allowed for a summary of data use efficiency, examining the occurrence of data collection, to feedback, and ultimately use. Figure 6 presents a decreasing trend exists from collection to feedback, highlighting this data efficiency. Feedback within the observed club is closely matched in value to the collection events. This shows that where data is collected, it is frequently fed back. Feedback for physical testing was greater than collection as information was delivered across different manners to different players, using data from the same collection points. Despite this frequent feedback, only around a quarter of days had an observed action based upon wellbeing and live monitoring. Lesser still, physical loading data only, influenced action on just two (8.3%) days. Testing data however did appear to positively action regular outcomes. Additionally, as mentioned, the evaluation of the impact of gym-based monitoring was not possible to assess.

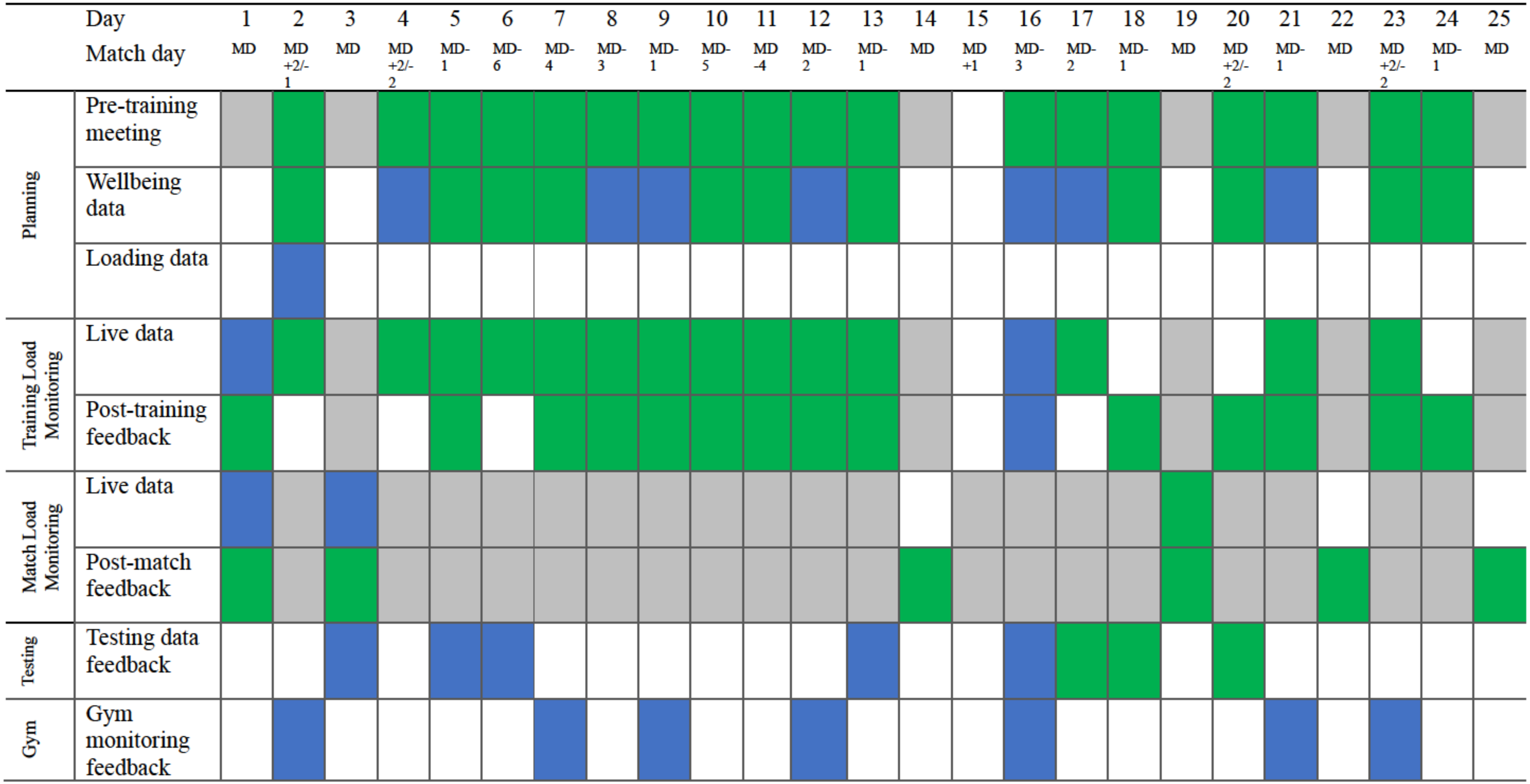


Figure 5: Overview of data use for grouped monitoring areas across the observation period. Green indicates data is fed back, blue highlights where a resultant action occurred due to data being feedback. (Note: training related data on day 1 reflects a field-based rehab training session.)

Monitoring Area	Wellbeing Data	Physical Loading (Training and Match)	Live Load Monitoring (Training and Match)	Testing Data	Gym-Based Monitoring
Collected Events (n)	19	24	18	6	19
Fed Back (n)	18	21	18	8	7
Action Taken (n) (% of collection)	5 (26.3%)	2 (8.3%)	4 (22.2%)	5 (83.3%)	N/A

Figure 6: Summary of data collection observations for monitored areas, in addition to observations of feedback, and resultant action taken.% value for the number of actions taken compared to the number of times collected is also expressed to highlight efficiency of data use.

4.3.3 Interviews

Following the observation period, interviews with the staff involved in the observation process were conducted. This provided an insight into staffs interactions with physical performance data, in addition to gaining an understanding of their knowledge of the data collected and fed back to them. This allowed for an expansion of the observational analysis, in addition to gaining a better understanding of why certain data may be used to action decisions within the club.

4.3.3.1 Planning

The observation schedule clearly identified physical performance data being collected, analysed, and used to support decisions related to planning. This process involved different members of staff, primarily during pre-training meetings. This second section of the interview therefore looked to explore the staffs understanding of the data they interacted with, in addition to the value it added to their planning process.

Staff recognised that performance data was important to this the planning process. This included both short term strategies, such as training sessions, in addition to longer player development strategies. They noted that the purpose of data is to 'create awareness' for:

"Those that help plan, for those that help make decisions" related to "planning, prepping for training, or a development plan for players." (Coach A)

"It now really goes into how sessions are planned, weeks are planned" in addition to "when it comes to recruitment…it's influential." (GK Coach A)

This idea of structured planning and the determination of training content from a physical viewpoint was further supported by comments from the interviewed physiotherapist.

Physio A believed there was now a greater knowledge of training load, with a "greater understanding of the balance between training hard and recovery" supporting elite athletes.

The pre-training meeting was recognised as a common touch point between staff, concurring with observational data. Coach A highlighted "the collaboration with different departments" to support the planning process. Coach B noted "pre-training we would clearly look at what that training day's going to look like". Regarding some of the content discussed within this meeting, coaches noted the type of session as being a major element. Coach C stated that during these pre-training meetings the targeted physical outcomes, such as exposure to high-speed running, are discussed. These outcomes are dependent on the session theme and proximity to matchday.

"For example, if we were in the morning meeting and it's an extensive day…we're looking at the total distance covered and we're looking at high intensity distance that our sports scientist would like us to hit"(Coach C)

Interviewed staff also noted the use of wellbeing data. Coach B used this wellbeing information to determine what players to have an individual follow up discussion with, to "understand where there are at from a mindset point of view". It was recognised by the coach that players may hide true feelings, such as fatigue, due to being "desperate to impress" and as such the conversation component was also important. This finding was important and stresses the value of the qualitative interviews, as it was beyond the scope of the observational analysis.

4.3.3.2 Physical Loading

After exploring the involvement of physical performance data in the planning process, the stakeholders were questioned regarding their use of physical loading data beyond planning. This primarily focused upon the use of on-field information and within physical loading reports provided post-match/training session.

Live monitoring produced in-session feedback, allowing for the possibility of immediate action to be taken. However, coaching staff appeared reluctant in their use of this data. Coach A noted it can't "be the driver", preferring to go on what they saw. However, they did appreciate the ability to be informed of anything significant by the performance staff. Coach B stated they wouldn't "actively seek it", since the session had been pre-planned. However, Physio A referenced the ability to monitor live was beneficial to their practice. This was supportive to their practice for sessions involving hamstring injury rehabilitation, whereby carefully progressing speed targets was crucial, and having the knowledge on-pitch meant this became informed practice.

An important finding from the interviews regarding post-training physical loading feedback showed that the coaching staff placed reliance in the performance department to highlight any noteworthy findings within the report. Coach B commented that should anything significant be flagged, "we can adapt and adjust for that". Coach C emphasised this point by noting that in a situation where a player was not at the appropriate physical loading level (overloaded or underloaded), the performance team would raise this issue with the coaching staff. This would likely result in additional or adapted training to facilitate this. This reliance on the performance staff to raise points of note led to Coach B stating that they did not "pay too much attention" to post-training reports. This was due to their belief that as the session had already been planned prior to training, the outcome would be close to expected. This was confirmed by Coach C when they stated:

"That's where I trust our sport science team to give us that information…I don't think that's one for me" (Coach C)

The reports were used by one coach to create an incentive for work rate and effort in training sessions. Through the establishment of a scoring system for specific physical outcomes (e.g., highest relative speed achieved), they felt that this provided them:

"Real insight into the players determination levels" (Coach C)

4.3.3.3 Physical Testing Data

The final area of examination involved data relating to physical capacity testing. Observational analysis had highlighted that this information was not used by other staff. This information was only interacted by staff other than performance practitioners during discussions and player reviews. As such, the interview aimed to explore any unobserved use and their understanding of why the data was collected.

GK Coach A highlighted the use of physical performance data in the implementation of interventions based on testing to support the development of their keepers. They noted the reflection of performance testing for "identified…weaknesses". They said:

"when we revisit that, we are hoping that these numbers are better" (GK Coach A)

It was identified by coaches that the data collected by physical capacity testing was used to create a "development plan for players". Coach A stated how the data could be used to create a "comparison" between players themselves and others within the club.

4.4 Discussion

This research aimed to present an ‘example’ club to examine the practices of physical performance monitoring, expanding upon the data landscape built in **Chapter 3**. This explored the data monitoring processes within a professional academy team, examining the areas of collection, through to the decisions and actions this data supported. Furthermore, through interviews, supportive qualitative information regarding stakeholders understanding and use of physical performance data was also established.

Observational analysis indicated that the data collection processes of the example club closely represented that seen in **Chapter 3** with performance staff collecting data points across key areas of performance. Data relating to daily practice, such as player wellbeing and physical loading was collected more often than testing or gym-based monitoring. This is likely owing to the data from these areas being used within daily functioning. Information was commonly shared during daily training planning meetings. These meetings integrated data from wellbeing reports and historical physical loading to determine training practices, player training involvement, and coach led discussions with players. Use of data was shown to impact several outcomes. One common use was in the planning process, where wellbeing data supported the decision to alter at least one player’s planned session within 27.8% of the training days. Despite the large volume of data being collected, and positive data use evidenced, inefficiencies were still shown to exist. Most of the collected data did not result in action. Whilst action is not always required, and the decision to take no action is still an action, it is important data monitoring processes are efficient and effective. The inefficiency viewed within this study is likely a function of how stakeholders interact with data. Through the qualitative information gathered by interviews, it was observed staff did not fully engaged with the data. Coach’s highlighted their desire to be informed of insightful findings, rather than seek out the information themselves. Elements such as live monitoring or post-training reports received very little interest from coaching staff, despite its frequent use and delivery by performance staff. The existence of these individual stakeholder differences is likely based upon personal experience, understanding of the data, and where this information fits into their personal philosophy of the player development process. This is an important aspect to consider, as it can assist in the understanding of how to target development within the use of physical performance data within soccer.

Monitoring Areas and Data Collection

In agreement with **Chapter 3** and previous literature, the volume of information collected, and the frequency of collection was high (Akenhead & Nassis, 2016). This saw over 140 metrics collected, on a regular basis across four key physical performance monitoring areas. These monitoring areas included planning, physical load monitoring, physical testing, and gym-based monitoring. These four main areas were used to support the physical development of players within the observed clubs.

Session planning established players' readiness to train status and determined the physical and technical/tactical demands of training sessions. Wellbeing data was the primary data source within this area. Subjective wellbeing has been demonstrated within adolescent elite athletes, as a useful marker in injury mitigation. Decreases in subjective scoring has previously been shown to precede an injury (von Rosen & Heijne, 2021). Therefore, this validated measure of readiness was collected before every training session to support decision making. By understanding players' readiness state, inappropriate physical loading could be avoided, mitigating injury risk (Noon, et al., 2015).

The second key area involved the monitoring of physical loading. Physical loading the most collected area of physical performance data, as recognised within **Chapter 3** and previous research (Akenhead & Nassis, 2016). Results also identified over fifty different metrics were collected within this data area, a similar number presented in previous research (Akenhead & Nassis, 2016). Despite the known issues relating to the possibility of data overload, it is still likely that clubs are gathering vast amounts of data from individual performance areas. The use of live physical load monitoring was also observed. This real-time monitoring provides practitioners with the ability to received instantaneous physical loading outputs (Catapult Sports, 2022). This can be used to ensure players are on track to achieve objective physical targets or provide between player comparison. During the observed period, live monitoring was conducted most during training sessions furthest from matchday (e.g., MD-3). Research has highlighted that these sessions typically have the greatest training load during the soccer microcycle (Malone, et al., 2015; Anderson, et al., 2016; Owen, et al., 2017; Stevens, et al., 2017).

Testing of physical capacities was also observed. This collection of physical performance data can allow for practitioners and coaching staff to assess a player's performance. This information was collected to review progress/regress from a physical standpoint and allow for informed programming of physical training to improve the athletes physical abilities (Taylor, et al., 2022). The improvement of physical qualities remains a key goal of player development due to the physical demands of soccer and the importance to remain injury free (Wisloff, et al., 1998; Wisløff, et al., 2004; Helgerud, et al., 2001; Eirale, et al., 2013; Hägglund, et al., 2013; Falch, et al., 2019). This data was collected from body composition analysis, with anthropometrical and skinfold data, in addition to the testing of physical capacities. This area yielded the greatest number of different metrics (87), with 71 metrics from physical testing. This volume of data agrees with practitioners responses within the survey in **Chapter 3**. Respondents noted the ‘explosion’ of data could be attributed to monitoring tools such as force platforms, a device used within the observed club. As practitioners now have access to tools previously only accessible in research facilities, this stresses the importance of explicitly understanding the data these devises can produce. Many of the possible collected metrics will likely produce little insight if not properly understood.

The final monitoring area was gym-based performance. This used a live velocity-based training tool to provide immediate feedback to players. This device produced a power output value, displayed to players during their lifting actions. Additionally, players recorded their repetition and load lifted data. This monitoring area produced the smallest data volume, with only three metrics.

Interpretation of this information shows the extensive collection of wellbeing data and physical loading is likely due to their ability to support and drive the daily functioning within the club. Data from physical testing and gym-based monitoring, was not observed to drive the daily processes, and as such, collection was less frequent. Results from the study allowed for this development of the understanding of data collection. Beyond this however, it also investigated these processes by which this data supported club-based functions and decisions.

Data Processes for Planning

Results identified pre-training meetings as the initial point of discussion involving physical performance data on training days. These meetings were attended by coaching, medical and performance staff and were used to design the session parameters. This included conversations around the modifiable training factors such as duration, pitch dimensions and player numbers. Through the manipulation of the training demand, physiological adaptations can be stimulated, driving development (Malone, et al., 2015; Anderson, et al., 2016). This collective effort between departments to design an appropriate training session from a physical loading perspective has previously been discussed (Weston, 2018; Nosek, et al., 2021; Balsom, et al., 2022).

Player submitted subjective wellbeing was observed to be impactful in the determination of players' training status and training session content was player. This data was shown to be a main decision-making factor in training involvement and loading. Decisions requiring action to be taken ranged in magnitude, from the modification of players' training load to complete removal from the session. Whilst removal of players was a rare occurrence (n = 2), conditions such as significant drops in subjective wellbeing may present a substantial enough indicator to do such, or greatly modify a player's planned loading (Noon, et al., 2015). This is important as the need for players to be in a physically ready state to perform is crucial to avoid decrease in physical outputs and increases in potential injury risk (Saw, et al., 2016; Heidari, et al., 2019). This consideration of what a player requires, was recognised by Physio A, who believed there was a "greater understanding of the balance between training hard and recovery" in the support of soccer players. This demonstrates the appreciation for fatigue in soccer players, and the requirement for extended recovery when considered suitable (Mohr, et al., 2005; Nedlec, et al., 2012; Hader, et al., 2019). Beyond the use of wellbeing data to inform upon player training status and content, one coach (Coach B) used the wellbeing data to determine what players to have a discussion with. This conversation was used to find out more about their state of preparedness, as the coach was aware that some players may mask the true extent of their readiness as they are “desperate to impress”. This was an interesting finding, as it highlighted the coaches ability to recognise the limitations of subjective reporting.

Supporting wellbeing data in pre-training meetings was the use of physical loading data to assist with the determination of training outcomes. This data was collected during previous days sessions. Physical loading data can be used to support planning, by attempting to avoid inappropriate loading. This can involve exposing players to a substantially greater physical load than they are prepared for (Gabbett, 2016). Only one occasion of physical performance data being used to influence a change to player’s physical involvement was observed. The lack of data required action is potentially due to previous days sessions achieving the planned physical loading, on most occasions. This would result in players being exposed to a planned and controlled physical load, in line with their current tolerance. This highlights the need to understand data use at the club level. Whilst **Chapter 3** noted the use of physical loading in session planning, the level of action being taken within a club may vary based upon their monitoring and planning practices.

Data Processes for Physical Loading

Physical performance data was collected to inform upon player’s physical activity and physiological response during training and match play. Collected data was analysed by the team’s physical performance coach, observing significant deviations from planned physical loading. Physical loading data was routinely fed back to stakeholders to provide an insight into player’s physical activity and response. This provision of feedback to key stakeholders is a common occurrence in soccer (Weston, 2018; Nosek, et al., 2021). It is viewed as a positive process that provides benefit to coaching and performance practitioners club's practices (Weston, 2018).

An immediate form of feedback was provided by the live monitoring technology. As observed, this technology was primarily used during training sessions furthest from matches, or during games themselves. As these training sessions were not in proximity of matches, they contained conditioning and training targeted towards physical development. As such, live monitoring was used to monitor the realisation of these physical demands. On match days, this technology was utilised to support the performance practitioner's decision making regarding post-match top ups. In collaboration with previous day(s) physical loading, this live loading data was used to prescribe the physical loading required by each player. As this data was fed back immediately, it expedited the decision-making process. This allowed for decisions to be made immediately at the end of the match, or before if required. Post-match sessions are conducted regularly to compensate for the reduced physical loading typically experienced by players beginning the match as a substitute. They may also provide an opportunity to induce beneficial physical development (Hills, et al., 2020; Balsom, et al., 2022).

However, it was identified that coaching staff did not use this live monitoring technology. Whilst they appreciated the ability of this monitoring tool, they did not believe it added value to their session and preferred to go off their personal judgment. Coaching staff preferred if performance practitioners raised any issues identified and would not "actively seek" any information. Similarly, during matches live monitoring of physical loading was observed, but only used by performance staff. This could be indicative of a lack of understanding by coaching staff, whereby education and more regular use of the tool within training may encourage engagement, expanding the possible uses of the technology. There was however greater interest in the use of live monitoring expressed by the physiotherapist to support their early-stage field rehabilitation sessions. This was used to avert potential overloading of players at the commencement of their return from injury (Taberner, et al., 2019). This use is likely driven by their awareness of the importance of specific loading metrics. If a similar understanding could be extended to coaching staff, this may increase use and help support physical development on-pitch.

One area not explored during the research was players perception and use of live data during pitch-based sessions. Previous research has highlighted that players are "likely" to change their effort levels during the session if shown their data live (Nosek, et al., 2021). Through collaborative action between all stakeholders, live monitoring could be better used to drive physical development in session, through increased visibility of real-time information.

Evidence from the qualitative interviews also showed that coaches did not use the post-activity physical loading reports for monitoring purposes. As physical loading had been discussed within the planning process, they felt it was unlikely that the session's physical outcomes would have deviated significantly. Importantly however, coaching staff highlighted that they took value from verbal feedback from the performance staff. This would mainly be through discussions of deviation from planned outcomes, or individual player concerns. This comment indicated that coaching staff relied on performance practitioners to highlight key factor contained within the report that may require further action. Should more of the physical loading reports have highlighted concerns, it is likely that staff would have acted according to the performance staff's recommendation.

This is important feedback, as one common barrier that has been presented in the sport scientist/coach relationship surrounds the translation of physical performance data into language coaching staff can successfully interpret (Weston, 2018; Nosek, et al., 2021). It implies that training reports alone are unlikely to contribute to action. The successful communication of data to coaching staff is an important asset in the ability for practitioners to influence successful decision making (Buchheit, 2017). This was noted during the interviews, where Coach C identified that due to a strong relationship between performance and coaching staff, where changes to physical loading were required, sessions and content could be adapted. This reference to the development of relationships to support action was also highlighted by respondents within **Chapter 3**. By establishing rapport, "buy-in" by staff to the data may increase. It is therefore considered important that performance staff ensure that in addition to providing feedback, they also ensure that it has been efficaciously understood by the coach or stakeholder.

Beyond physical loading reports for monitoring purposes, one coach used this information to form a competitive ranking system based off physical outputs. This was completed to engage players and drive effort of players within session. This concept is supported by previous research examining the feedback of GPS training data, whereby coaching, performance and playing staff all believed sport science data to be "very important" to the 'assessment of effort' (Nosek, et al., 2021). Use of monitoring tools therefore may also serve as a method of stimulating player development through an increase of one's volitional drive, through external motivation, prompting greater physiological development through increased external outputs (Wing, 2018; Impellizzeri, et al., 2019). It is therefore prudent that performance staff do not limit the use of data to that of which they understand. Other stakeholders, if allowed access to the information, may be able to positively expand its influence within the club. In turn, this could generate further buy-in from coaching staff to the monitoring processes.

Data Processes for Physical Testing

Data originating from physical testing was almost exclusively used by the performance practitioners. Action taken from feedback primarily led to development programme changes. This included individual physical development plans, or the establishment of targets within the physical performance department. Whilst this information was routinely fed back to other stakeholders, and coaching staff stated their desire to know about this information, they were not observed to act upon this information. This finding is not unexpected due to the role of physical performance staff leading the physical component of development. Coaching staff did however recognise the purpose of this and expressed their interest in follow-up testing data to observe changes. Staff also valued this information within wider club-based outcomes, such as those related to retention of players. This was recognised by a member of coaching staff when they started that physical performance data ultimately led to "decisions…about retention". This statement disagrees with a previous finding, whereby coaching and playing staff believed sport science data was "not important" regarding player retention (Nosek, et al., 2021). However, it is likely that this belief is highly specific to individuals, based upon their club model, experience with physical performance practitioners and data, and openness to new information. In some instances, the physical qualities of players are sensitive enough to discriminate between playing level (Impellizzeri, et al., 2008), suggesting that physical performance data could provide a benefit towards determining the playing level of a player.

Data Processes for Gym-Based Monitoring

Gym-based monitoring produced the lowest data observation. Data from the VBT device were primarily used to drive motivation during power-based exercises and ensure athletes were working within their targeted velocity band, a usage commonly discussed within research (Weakley, et al., 2020; Thompson, et al., 2022). This information was fed back immediately to players. However, as outlined within the results, identification of action taken was not possible. Given the lack of research that exists regarding gym-based monitoring within soccer, and the limited application within the observed soccer club, this may be an important area for future research to focus upon.

Interpretation of Data Monitoring Practices

The results of this research have shown that a high volume of data is collected and fed back, resulting in some action to support player development. Figure 6 evidenced that the total amount of action taken was relatively low in proportion to the volume of data collected. This study does not allow for this to be determined as positive or negative, rather it documents how much information is collected for so few actions. This may be due to the clubs training plan and monitoring achieving the expected outcomes, mitigating the need to make adaptations. As such, no action, may be an action. Crucially however, results indicated a lack of efficient and effectiveness in how coaching staff interact with the data. It is possible that this impacted upon the overall data use.

Results show that coaching staff are primarily passive unless change is 'activated' by the performance staff. Staff recognised their lack of engagement with both monitoring tools and the feedback. This may be indicative of not fully understanding the information presented, or not being interested in the data to support practice. Results showed that when the practitioner raised concerns, resultant action would happen. Positively, this likely indicates that staff were open to the use of data, and there was trust in the performance staff to make these decisions. This openness to use performance data and support decisions was likely benefited by the length of time all staff had worked together for. This had allowed for the development of relationships, resulting in the trust and “buy-in”, referenced as being required to support the use of data (**Chapter 3**). Research has previously shown strategies to improve coach “compliance” included establishing “trust” and the importance of clear and informed discussions to educate coaching staff (McCall, et al., 2016). However, it appears evident that through the further development of coach’s understanding of monitoring practices, and the data collected, data use and interaction could improve. In turn, this may benefit the player development process, due to the influence coaching staff have upon decision making within the club.

Given the likeness between the ‘model’ club and findings from **Chapter 3** and previous literature, it could be surmised that many of the reported findings from this study likely manifest in many other clubs across professional soccer. As such, the efficiency and effectiveness of data collection, analysis, feedback, and use is likely an issue that permeates soccer clubs. It is therefore important to consider methods of how to improve staff understanding of data and support engagement. By achieving this, it would be hoped that further benefits to monitoring practice can develop.

4.5 Conclusion

Performance staff and the data that they collect play a key function in the support provided to soccer teams. Outcomes of this research have highlighted that in agreement with **Chapter 3**, a wealth of information across multiple performance areas is collected. This research expanded upon this to explore the processes by which this collected information can be used within a professional senior academy team. Common touch points between staff, such as pre-training meetings utilise performance data that can be used to inform decisions such as training content and player involvement. Physical loading data can be used on pitch to action changes to player's session, whilst post-training reports can influence the physical loading of following sessions. Interviews noted an important finding, highlighting that coaching staff relied on their performance support staff to aid their understanding of player's physical status and determine appropriate actions if required. Coaching staff noted their preference for verbal feedback. Whilst feedback can be provided, it is important coaches both understand this information, and value and trust what is being provided. This necessitates the establishment of an effective working relationship between stakeholders and performance staff. By understanding the processes that take place within a club relating to data use and decision making, the foundation for an intervention to improve physical performance data efficacy can be created.

PHASE 3 – INTERVENTION TO UNDERSTAND AND IMPROVE PHYSICAL PERFORMANCE DATA EFFICIENCY AND EFFECTIVNESS

CHAPTER 5:

EXPLORING THE RELATIONSHIP BETWEEN PHYSICAL LOADING METRICS AND PHYSICAL PERFORMANCE CAPACITY TESTS IN THE IDENTIFICATION OF INFORMATIVE INSIGHTS TO SUPPORT FOCUSED DATA FEEDBACK

5.0 Introduction

Results from Chapter 4 have highlighted the following key aspects.

- Stakeholders are likely to remain ‘inactive’ to data unless findings are presented to them by performance staff
- Stakeholders understanding and use of data is likely limited by personal experience and the relationship they have with their performance staff.

The initial research phases have explored the landscape of physical performance monitoring, in addition to the processes that use physical performance data to support player development decision making. The findings from this research have shown the main purpose of monitoring within youth soccer to be the development of physical capacities. It has also evidenced the way physical performance data is provided to stakeholders. Practitioners routinely interact with data during pre-training planning meetings, in addition to post-training discussions and through the provision of digital reports. However, inefficiencies in data monitoring have also been identified. Data collection still draws in a large volume of data, ‘some’ to ‘most’ of which goes unused. Furthermore, not all the processed data is impactful, in that it does not yield an outcome, whether or not it is fed back. Whilst not every item of data collected necessitates a resulting action, data collected must be meaningful to the purpose of collection. Additionally, even where data is appropriately collected and fed back, gaps in coaches understanding of the information, or a lack of trust in the data and/or practitioner, may hinder the ability of this information to support positive change. This research phase therefore will attempt to improve upon data use processes, utilising ‘slow’ research to produce meaningful informative insights to instigate change to the data feedback process.

As outlined in previous chapters, soccer is a physically demanding sport. Whether a youth player requiring development of physical capacities to aid their transition into senior soccer (Elferink-Gemser, et al., 2012; Mills, et al., 2012; Raya-Castellano & Uriondo, 2015; Morgans, et al., 2022) or a senior player requiring elite physical traits to support performance levels (Apor, 1988; Wisloff, et al., 1998; Helgerud, et al., 2001; Arnason, et al., 2004; Eirale, et al., 2013; Falch, et al., 2019), the development of physical attributes is important.

Exposure to sufficient physical loading can induce physiological changes, resulting in improvements to physical capacity (McMillan, et al., 2005; Bradley, 2022). Physiological adaptations can be targeted by exposing player's to a specific physical output, resulting in an internal response that drives change (Fitzpatrick, et al., 2018; Impellizzeri, et al., 2019). Such changes in the physical capacity of players can be detected using physical capacity testing. Testing can provide important insights into individual strands of physical performance, at an individual level, such as exploring the fitness levels of players, or their ability to express maximal force through specific muscle groups (Hoff, 2005; Taylor, et al., 2022). Not only does testing allow for a snapshot of an individual's present performance capacity, but it also allows for the documentation of changes in performance, potentially in response to physical loading or a specific training intervention.

This ability of practitioners and researchers to monitor the combination of physical outputs and the respondent change in performance capacity through testing has allowed for research into the drivers of change. Termed dose-response, this explores the relationship between physical stimuli and level of change to capacity. If understood, this relationship could be exploited to develop specific physical qualities of players. However, at present, there appears to be considerable uncertainty regarding the relationship between physical loading and physical performance development. Understanding of these relationships is important to developing impactful data monitoring processes to support the objective of athletic development.

A dose-response relationship has been reported between perceived exertion levels and changes to in aerobic fitness levels of youth soccer players (Gil-Rey, et al., 2015). Increased perception of respiratory and muscular exertion, in addition to training volume, correlated with positive changes to aerobic fitness. Furthermore, research by Fitzpatrick and peers (2018) highlighted the potential use of monitoring the time player's spend within individualised speed thresholds to develop fitness. The authors highlighted a "stronger" relationship to fitness changes when monitoring individual's activity profiles, based upon distinctive running thresholds, as opposed to "common" thresholds, such as high-speed running (>17 $km.h^{-1}$). Interestingly, this research also identified that metrics that were commonplace within monitoring practices may not provide a clear insight into physiological development, potentially undermining their use within current monitoring practices. This stresses the importance of practitioners understanding the data they collect and its purpose for being monitored, in addition to what it *actually* measures.

Dose-response relationships for attributes other than fitness have also been conducted. One study examining semi-professional soccer players completed two interventions over two-weeks of pitch based repeated sprint training (Taylor, et al., 2016). The authors recorded improvements in acceleration and speed. Interestingly, despite one of the intervention types requiring a greater physical output and physiological response, there was an "unclear" difference compared to the less physically demanding method, that still elicited improvements.

Whilst promising, the referenced research examining dose response have focused on specific physical interventions, with small participant groups, of varying performance levels, across short periods of time (i.e., several weeks). Further research has produced results showing a lack of consensus regarding what metrics support change, with conflicting reports being presented by authors (Rabbani, et al., 2019; Younesi, et al., 2021). This indicates the complexity that exists between training and response, suggesting potential individual differences occur. Furthermore, there is the potential of other, non-measured factors that may impact performance, such as changes in body composition, and strength levels (Clemente, et al., 2019). Additionally, the selected tests may be sensitive to the monitored physical metric, with studies highlighting a different dose-response between two methods of fitness tests (Rabbani, et al., 2019; Younesi, et al., 2021). This implies that changes to performance may only be detected by one specific testing protocol. Overall, the picture of dose-response measurements appears shrouded in conflicting statements regarding impactful metrics associated with positive changes in physical capacity, individual differences in response, test selection, and the limited periods of intervention observation. It appears that these studies are restricted to the testing protocols and participant cohort.

Further work in this area is important, however. Through a greater understanding of the physical outputs that stimulate improvements of physical qualities, better informed decision-making processes may be taken around training design to target specific physiological development (Fitzpatrick, et al., 2018). In collaboration with coaching staff, this could result in changes to the structure of training within different phases of the season (e.g., boosting aerobic fitness in pre-season), or be used to provide a targeted intervention aimed to improve an individual or group specific physical attribute (Taylor, et al., 2022).

However, as documented in published research and this project (**Chapter 3**), there is a wealth of metrics collected by practitioners, resulting in ineffective translation and potential poor understanding of what is being analysed (Akenhead & Nassis, 2016; Weston, 2018; Ward, et al., 2019; Ryan, et al., 2021). Therefore, an effective skill of practitioners is the ability to narrow their focus of their collected data to ascertain the information that provides them with their desired output.

By narrowing the focus of data that is collected and fed back, this may assist in reducing some of the inefficiencies seen across this research project. Through the identification of meaningful physical loading metrics, this may support the planning process by providing greater but narrowed focus. This step may also aid coaching staff better understanding physical demands by simplifying the learning required. **Chapter 4** highlighted coaches lack of engagement with live load monitoring and post-training reports. By establishing ‘key’ metrics, with a relationship to physical development, coach “buy-in” and understanding may increase. In turn, this should promote more efficient and effective use of data.

Therefore, this study aims to explore the processes involved in extracting insights from the complex data sets routinely collected from physical loading (Akenhead & Nassis, 2016). Due to the variation seen between groups and testing protocols within previous research, these insights will likely be specific to the observed group and testing battery employed. However, it is hoped this research process can support application within other environments. It has been proposed to reduce the inefficiencies that have been identified within the data collection and analysis processes. Following data analysis, results will be used to conduct an intervention within a club’s feedback process, aimed at supporting coaches decision-making process in relation to session planning.

5.1 Methods

5.1.1 Study Overview

This study examined changes in physical capacities of elite youth soccer players across fourteen months of U18 and B team soccer. These capacities were related to the key physical components of soccer performance, fitness, speed, strength, and power (**See 2.2 Physical and Physiological Soccer Demands**). Simultaneously, the physical loading (external and internal) of these players was also recorded. Throughout the monitored period, there was no targeted physical intervention employed. Rather, players were routinely exposed to isolated conditioning, repeated sprint efforts, football related training, and match play, as part of their normal practice within the club. This natural environment study design was used to present a 'typical' physical loading profile accumulated through training and match play.

Linear mixed modelling (LMM) was then used to determine if changes in physical capacities were influenced by the physical loading and physiological response experienced by the player. From this analysis, the physical loading metrics that presented the strongest relationship with changes in physical performance could potentially be determined. This would then assist in determining the physical loading metric(s) best associated with these physical capacity changes. In turn, this/these metric(s) could then be used for a targeted physical intervention, conducted by the implementation of a focused feedback strategy.

5.1.2 Participants

Forty-four full-time youth soccer players (age: 17.7 ± 1.6 years) from two age group squads (U18 and B Team/U21) of a professional soccer academy were involved within the study. Only players who remained at the club for the duration of the fourteen months were included within the study.

5.1.3 Physical Performance Testing

Testing was conducted on training days separated from strenuous activity (e.g., match play) by at least 72-hours to support the restoration of physical qualities. The testing battery was designed by the club, used to assess their key physical performance attributes. Testing was completed indoors, on an astro-turf football pitch, to ensure consistency of testing surfaces and environmental conditions. Tests were all completed in the morning. Whilst this may not be the preferential time for all athletes, due to the impact of circadian phenotypes, it promoted consistency of testing conditions (Facer-Childs & Brandstaetter, 2015). A standard warm-up protocol lasting ten minutes, consisting of static and dynamic stretches, in addition to dynamic movement was performed by all players, prior to testing. The warmup and order of tests was consistent, to prevent any changes in impact from physical conditions, such as post-activation potentiation (Lorenz, 2011; Petisco, et al., 2019). Should an individual performance test not have been completed, for any reason, testing order remained consistent.

Testing schedule was dictated by the club, with tests scheduled for the start of pre-season, end of pre-season, mid-season, and end of season. Across the fourteen months, players completed an average of 4 ± 1 physical performance test. Overall, eight testing points existed, outlined in Figure 7. Whilst the preferred testing schedule would have all players test on the same day, player availability was interrupted due to international squad call ups, senior team involvement, injury, and illness. This resulted in follow up testing days occurring to ensure all players were tested within a similar stage of the season (test 2, test 3 and test 5). This testing schedule however emphasises the dynamic nature of performance monitoring within elite soccer, again creating a more relatable and valid study environment. Testing for speed, power, strength, and fitness qualities all utilised validated and commonly utilised methods of assessment.

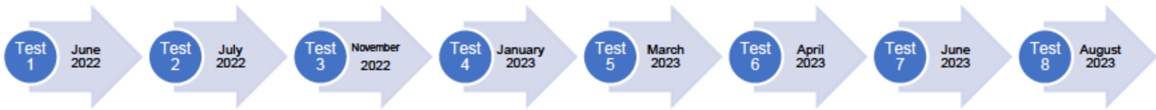


Figure 7: Testing points across the monitored period, highlighting test number and date.

5.1.3.1 Speed Assessment

Speed testing was conducted using a linear sprint assessment, measured by dual-beam photocell timing system (Witty, Microgate, Bolzano, Italy). Timing gates were placed on the 0m line and 10m line, at a height of 0.8m. Athletes started from a standing start, with their foot on a line 0.3m behind the 0m mark, to reduce the likelihood of a false trigger of the timing gate. Following their warmup, athletes completed three maximal 10m effort. Such procedures have been used in previous studies (Harper, et al., 2020). Timing gates have also been noted as the “recommended technology” to accurately measure sprints (Haugen & Buchheit, 2016; Colino, et al., 2019).

5.1.3.2 Jump Assessment

The countermovement jump (CMJ) is a common method of jump performance and power assessment in soccer. Performance was monitored using a dual force plate (FD4000 Forcedeck dual force platforms, VALD Performance, Sydney, Australia). Jump protocol was the same as previous research (Heishman, et al., 2018; Harper, et al., 2020), with players ensuring their hands remained on their hips throughout the entirety of the jump. This negates any jump benefit through additional propulsion generated from arm swing. It also acts to standardise the jump efforts between athletes. Jump height, determined from flight time was the primary metric of assessment. This metric was previously shown to have acceptable levels of reliability (intraclass correlation coefficient (ICC = 0.97) (Merrigan, et al., 2021).

5.1.3.3 Strength Assessment

Hamstring strength assessment was conducted using a portable strength system (Nordbord, Vald Performance, Australia). Bilateral eccentric hamstring strength was assessed using a Nordic hamstring curl. This followed the protocol outlined in previous research (Bishop, et al., 2022). Athletes were instructed to “drive their heels to the roof”, pushing up on the ankle brace. They performed two warm up efforts at a subjective effort of 70% and 90%, prior to two maximal efforts. Reliability of the Nordic curl force production using the same testing equipment was shown to be “good” (ICC = 0.87) (Ferguson, et al., 2023).

5.1.3.4 Fitness Assessment

Fitness was assessed through the 30-15 IFT. The protocol has been outlined by the tests creator (Buchheit, et al., 2021). Athletes perform shuttle runs of increasing speed for 30-seconds, interspersed with a 15-second recovery. Where athletes failed to reach the required zone on the auditory signal, they were given a warning. Three consecutive warnings on the same speed level resulted in the player being withdrawn from the test. An individual’s final score was given as the speed of the level of their last full completed stage. This method of assessment has been shown to demonstrate excellent levels of reliability, contributing towards its ability to determine changes in performance (Buchheit, 2008; Grgic, et al., 2021)

5.1.4 Load Monitoring

External load was recorded using player-worn GPS units (Vector S7, Catapult Sports, Melbourne, Australia). These GPS units sampled at 10 hertz (Hz), with internal accelerometers sampling at 100Hz. Players wore their designated unit for all sessions in a tight-fitting vest, with the unit secured in a Velcro locked holder, positioned between the scapular. Similar protocol and validation of this method has been discussed in previous research (Fitzpatrick, et al., 2018). Internal load was also recorded using the GPS unit via a connected player-worn heart rate unit (Polar H9, Polar Electro, Kempele, Finland). This unit was attached to a chest strap, fitted tightly just below sternum level, monitoring heart rate activity. Following all activity, external and internal loading data was downloaded using the GPS provider's software (Catapult Openfield, Version 3.0. , Catapult Sports, Melbourne, Australia).

Of all collected metrics, six were used for this research. A summary of the collected metrics is presented within Table 7. They were selected due to their common use by practitioners. Evidence to support this comes from both unpublished data collected from the survey in **Chapter 3** and published researched. Unpublished analysis showed 92.3% of practitioners collected total distance, 97.4% collecting high intensity distance and/or sprint distance and 76.9% collecting acceleration/deceleration data. Research by Akenhead and Nassis (2016) highlighted the selected metrics as amongst the most popular collected by practitioners across training and match play. Whilst internal loading was not as popular, heart rate exertion was selected as the metric to monitor internal load. This metric is used to "assess cardiovascular load" (Sellars, 2023). It applies an increasing weighting factor to the time in seconds, spent in each of eight heart rate bands. Whilst this metric is specific to Catapult (Catapult Sports, Melbourne, Australia), it applies the same principal as training impulse (TRIMP).

Analysis conducted within this research aimed to reduce the complexity of metrics collected, an inefficiency noted in the monitoring process (**Chapter 3**). This lowered the loading metrics used in the analysis process to a single external and internal loading value. Total distance and heart rate exertion were selected due to being amongst the most used, as presented in previous research (Akenhead & Nassis, 2016). This was completed due to potential issues of data overload in soccer, with multiple metrics being used to assess similar concepts, and to improve data collection and analysis efficiency (Akenhead & Nassis, 2016).

Table 7: Summary of selected physical loading metrics, their attributed loading type, and the unit in which they are collected

Physical Metric	Loading Type	Measure
Total Distance (TD)	External	metres
High Intensity Distance (HID) (>5.5m.sec^{-1})	External	metres
Sprint Distance (SD) (>7.0m.sec^{-1})	External	metres
High Intensity Decelerations (HIDec) (<-3.0m.sec^{-1})	External	count/number
High Intensity Accelerations (HIAcc) (>3.0m.sec^{-1})	External	count/number
Heart Rate Exertion (HREx) (au)	Internal	arbitrary unit

Again, typical of real-world soccer, the possibility of additional training (e.g., individual training) beyond that monitored within the club exists. This was not included in the loading data. The duration of this study acts to both increase the likelihood of such events occurring, due to the length of monitored time. However, this may also act to reduce the impact of such non-monitored sessions, due to volume of collected data. Additionally, off-field work, including gym-based physical development sessions were not monitored. The potential impact of this will be explored within the discussion.

5.1.5 Statistical Analysis

Prior to analysis, data was rescaled to have a mean of 0 and a standard deviation equal to 1. Three series of LMM's were conducted on the four test variables. In the first series, total distance, high intensity distance, sprint distance, high intensity accelerations, high intensity decelerations and heart rate exertion were used as fixed effects (physical loading), and player ID was used as a random effect. In the second series, LMM was conducted using the same fixed effects, but with the addition of the participant's previous score for that test. In the third and final series, LMM was conducted using only total distance, heart rate exertion and the previous test score. Within each LMM, the physical loading and physical capacity change was calculated between each individual testing points (e.g., difference between player 1's 30:15 IFT test point 1 and 2), for every player. The outcome variable is therefore the change in test score.

The use of previous test score provided a proxy marker of player's likely capacity at the point of testing. For each LMM, a conditional coefficient of determination (R^2) was calculated using a root mean square approach. Final analysis documented this R^2 value for changes in endurance to the individual loading metrics, in addition to previous testing score.

5.2 Results

5.2.1 Relationship Between Physical Performance Tests and Physical Loading

Initial analysis explored the relationship between all the selected external and internal loading metrics with changes in physical performance capacity testing. This was used to determine the variance in performance testing likely explained by the physical loading. When examining explained variance of all training load metrics only, changes in fitness, as assessed by the 30:15 IFT appeared to have the strongest relationship ($R^2 = 0.34$). This is closely followed by the CMJ ($R^2 = 0.33$). However, the explained variance is recognised as being quite low. The breakdown of explained variance between physical load and all tests is shown in Table 8.

Table 8: Explained variance (R2) between performance tests and physical load only.

Test	Physical Load
10m (sec)	0.13
CMJ (cm)	0.33
30:15 IFT (km/h^{-1})	0.34
Nordic Curl (N/Kg)	0.10

Based on this first model, an effort to improve the relationship between physical loading and changes in performance was completed by incorporating the athletes previous score. This was used as a likely indicator of current capacity. This was successful for increasing the relationships (explained variance) for most tests. Again, the 30:15 IFT demonstrated the strongest relationship in the model. The Nordic curl was the only test that did not demonstrate a higher explained variance when previous score was incorporated into the model. The breakdown of explained variance between physical load and previous test score, and all tests is shown in Table 9.

Table 9: Explained variance (R2) between performance tests and physical load and previous test score.

Test	Physical Load + Previous Test Score
10m (sec)	0.54
CMJ (cm)	0.44
30:15 IFT (km/h^{-1})	0.76
Nordic Curl (N/Kg)	0.10

The final analysis model explored the relationship between two commonly used loading metrics (external: TD, and internal: HREx). This was conducted to counter the complexities and inefficiencies seen in data collection for physical performance monitoring. There was no observed large decrease in explained variance across any of the tests. Again, the 30:15 still demonstrated the greatest explained variance. The breakdown of explained variance between TD and HREx, and all tests is shown in Table 10.

Table 10: Explained variance (R2) between performance tests and focused physical load metrics, and previous test score.

Test	TD and HREx + Previous Test Score
10m (sec)	0.45
CMJ (cm)	0.41
30:15 IFT (km/h^{-1})	0.68
Nordic Curl (N/Kg)	0.11

5.2.2 Changes in 30:15 IFT Test

As detected in Tables 8-10, the 30:15 IFT test appeared to be the physical capacity test most influenced by physical load. This relationship was strengthened when the athletes starting score was included in the model (Table 9 and 10). As such, it became the focus of further analysis. Table 11 models the coefficient value and significance for individual training load variables and previous testing scores.

Table 11: Linear mixed modelling results of change in 30:15 IFT with selected physical loading metrics, in addition to test start result. All results are standardised, as per statistical analysis methodology. Bold highlights the metrics that were analysed further within the model.

	Coefficient	95% CI	P value
Intercept	0.356	0.054 to 0.658	0.021
TD	**0.686**	**-0.186 to 1.558**	**0.123**
HID	-0.307	-1.350 to 0.736	0.564
SD	0.499	-0.225 to 1.223	0.177
HIDec	0.197	-0.323 to 0.716	0.459
HIAcc	-0.499	-1.249 to 0.252	0.193
HREx	**-0.373**	**-0.838 to 0.091**	**0.115**
Previous Test	**-0.318**	**-0.648 to 0.012**	**0.059**

Analysis highlights that none of the loading metrics presented a significant finding, despite some of the large values. This is due to all 95% confidence intervals (CI) crossing zero. Total distance presents the greatest coefficient, with a rudimentary finding suggesting that greater total distance will equate to a greater physical fitness adaptation. In respect to HREx, a negative coefficient is presented. A finding of this could be that whilst athletes can produce and sustain high physiological outputs, they may not be potent enough to stimulate any further adaptation. Similarly, the previous testing value produced a negative coefficient value. This could be indicative of fitter athletes not being able to increase their testing performance, with present physical loading. Together, these results highlight that there is a strong, yet complex relationship between physical load and fitness, some of which could be attributed to contextual factors not assessed within this study.

5.3 Discussion

This study aimed to identify meaningful insights for the purpose of developing focused data feedback. To support physical development, a key physical performance monitoring objective, training can be used to expose player's to a sufficient physical stimulus to promote a physiological response. However, reduced efficacy of data supported decisions, owed to information overload and poor translation of information has been evidenced. Data analysis attempted to explore the relationship between physical loading and four physical tests to identify key metrics to support evidence-backed feedback to support physical development. These models highlighted those physical tests closely related to the typical on-field movement patterns, being monitored by physical loading, had a stronger relationship than those further removed, such as the Nordic curl. To further improve the relationship, previous testing scores were incorporated into the model to act as a likely indicator of starting physical capacity. This was successful in enhancing explained variance between the tests. The final model assessed the relationship between fitness and training load, using only two common metrics, resulting in only a slight reduction in explained variance. Results indicated that increasing training load through greater total distance may enhance player fitness, as assessed by the 30:15 IFT. However, internal response and previous scoring of players should be considered. Players with greater starting fitness levels and physiological tolerance may require a more potent training stimulus to continue to physically develop.

Chapters 3 and **4** identified inefficiencies within the data monitoring processes, across both multiple professional clubs, and within a single club. These insights recognised that data monitoring collected a high volume of data, much of which went unused. Furthermore, whilst use of this data presented positive findings, feedback of the data could be strengthened through coach education and establishment of stronger relationships with performance staff. **Chapter 4** agreed with these findings, whilst also establishing areas of potential development. One such area included the education of coaching staff regarding physical performance data. By developing a greater understanding of metrics that have a close relationship with physical development, informative insights that could produce meaningful change could support this process.

Analysis of loading and testing data initially indicated that external physical loading and internal response explain only a small proportion of the change for the selected physical tests within this study. This is largely unsurprising due to the myriad of components that may exert influence over changes in physical capacity, beyond pitch based physical loading. The development of strength and power qualities (e.g., CMJ, Nordic Curl) , likely receive greater developmental contribution from resistance training (Lorenz, 2015). Expanding beyond the scope of this discussion, factors such as nutrition can determine an athletes response to training, adding to the complexity of identifying true causes of change (Stokes, et al., 2018). This stresses the importance of applying context to physical changes and not assuming association between a single physical stimuli and performance adaptations. Furthermore, physical performance monitoring should present a unified approach to ensure a full picture of player development. Whilst this research was limited to on-field physical loading, insights from other areas of physical performance may provide a more detailed picture of the athletes performance. Together, this could result in a greater understanding of performance changes. Whilst data use is expansive and many practitioners place trust in the information they receive from their technology, practitioners must also exercise caution when it comes to interpreting results and changes based off collected data.

However, an important finding with potential to impact player development centres around the response of individual players to training load across a long period of training, particularly those with more developed physical attributes. Table 9 shows that a player's previous physical capacity score exerts a large influence over their subsequent response to physical load. It is recognised that this 'previous score' is likely not representative of the athletes exact physical capacity at the time of testing, due to the length of period that existed between testing points (Figure 7). However, it provides a likely indicator of an individual's probable physical capacities. Of the physical capacities assessed, physical fitness appeared most responsive to physical loading. As such, the discussion will continue with focus upon this quality.

On-field training does appear to have an influence upon fitness, as assessed by the 30:15 IFT, a finding that agrees with the previous literature (Gil-Rey, et al., 2015; Fitzpatrick, et al., 2018). Table 11 suggested that increases in total distance presented the strongest correlation with improvements in physical fitness testing. This concept of simply increasing overall volume to improve fitness has been seen in previous studies (Gil-Rey, et al., 2015; Campos-Vazquez, et al., 2017). Whilst the referenced studies examined perceived training load, through rating of perceived exertion, and training duration, it is conceivable that a greater overall load would support some positive adaptation.

An interesting finding, also highlighted in Table 11 shows a negative correlation between HR exertion and 30:15 IFT scoring. This is contrary to lay belief that a greater internal response will promote positive physiological adaptations that will result in a higher 30:15 IFT score. Previous research has promoted the notion that increased red zone minutes (time > 90% maximal HR) increases fitness levels (Hoff, et al., 2002). However, work has illuminated the need for understanding individual's internal response (Akubat, et al., 2012). What must be considered, is the ability of soccer training to continue to elicit a potent stimulus to drive development. Practitioners must consider the potential that with chronic exposure to training, exercise of the same demand will no longer possesses the ability to stimulate change. This is likely due in part to the 'general' training methods employed within team sports, aimed at working all athletes together (Clemente, et al., 2019). Whilst players may still accumulate high values for HREx (or any other internal response metric), this may not be enough to drive further change. Due to physiological adaptation, players will be better developed to cope with the physical demands. This finding therefore leads to the result that for adaptation to continue within the monitored participants, training is required to become more demanding for players to continue development of individual physiological adaptation. Practitioners therefore must be aware of their athletes physical profile and appropriately account for individual responses to exercise.

Similarly, previous testing score also presented a negative correlation value of -0.318. Whilst training is likely planned with physical development in mind, it appears that as players physically develop, the return on development of physical qualities reduces. This concept could be explained through the law of diminishing returns, where if variables remain constant, continued development is unlikely. This may be indicative of players not being presented with the opportunity to continue physical development, limited by the physical demand placed upon them across the duration of this study. This study deliberately did not implement a targeted physical development intervention, as seen in other studies. This provides practitioners with a clear understanding of the need to appropriately stress their athletes to induce physical development. Furthermore, this finding again stresses the importance of considering the individuals physical capacity when attempting to attain physical development. This study presents the idea that increases in external loading, through total distance, and an increase in internal demand, especially for those with greater starting fitness levels, may be required to stimulate further physical development. Such changes in physical loading may not be the primary drivers of fitness improvement, however, it modifies the variables potentially limiting change.

As identified in previous chapters, the purpose of monitoring within the youth level of soccer is to develop physical qualities with the goal of preparing players for the transition to senior level soccer. However, current performance monitoring is fraught with many issues. These include metrics collected without clear purpose, an overload of information, and poor translation of insights into practice. Additionally, monitoring of changes in performance is required to assess the efficacy of training to develop physical capacities. These tests should be validated, reliable and consistent across the monitoring period.

5.4 Conclusions

Physical performance data can be made more impactful by determining insights that can result in more efficient and effective decision making. This study identified that data monitoring is a complex process, with difficulties in obtaining cause and effect. The research highlighted that targeted analysis can be used to narrow down the collected and analysed metrics. This narrowing in metrics can also come without significant reduction in its correlation to what it is being used to analyse. Whilst this is positive in potentially increasing the efficiency of data analysis, using these metrics to improve performance remains challenging. This is because many factors are involved in physical development, potentially beyond the scope of current monitoring practices. However, rudimentary insights can still be taken from the analysis. Whilst one specific targeted loading metric to improve fitness was not identified, modifying the physical demands placed upon players could result in a positive response. Results indicated that increased total distance and greater heart rate exertion may support physical development. However, consideration of athlete's starting fitness is important, especially for fitter players. Together, this narrowing of physical metrics used to target this physical capacity could support more effective translation into practice, through simplified decision making, and easier translation of information.

CHAPTER 6:

IMPLEMENTATION OF EVIDENCE INFORMED DATA INTO THE FEEDBACK PRACTICES OF AN ELITE YOUTH SOCCER TEAM

6.0 Introduction

Results from Chapter 5 have highlighted the following key aspects.

- Physiological development is likely a function of multiple inputs, none of which can be simplified to a single metric
- The development of fitness, as assessed by the 30:15 IFT appears to be influenced by on pitch physical loading.
- Through increasing total distance, it is possible that fitness levels assessed by the 30:15 IFT may improve. Within the sample population, it also appears evident that the internal demand placed upon players may not be sufficient to stimulate further fitness improvements.

Physical performance monitoring should collect data from which valuable insights can be extracted. In turn, this information should be fed back and used to support decision-making processes within a club. As detailed throughout **Chapter 3** and **Chapter 4**, physical performance data can be used to drive physical development through supporting decision making. Research has however evidenced concerns regarding the efficacy of collected information in the support of these processes. The volume of data currently collected significantly outweighs use, meaning that many collected metrics are redundant. Furthermore, coaches have also reported a lack of understanding of data, due to information overload and poor translation. **Chapter 4** emphasised the importance of practitioners establishing trust with coaching staff. This should be supported by the provision of clear information, due to coaches preferring to receive key physical loading insights, rather than seek it out from reports themselves. To aid this, **Chapter 5** aimed to establish focused and meaningful physical loading metrics with a strong relationship to physical fitness. Following statistical analysis, two metrics were selected to drive a novel feedback strategy to evaluate the impact data-driven processes can have within an elite youth soccer club.

One area this data can be used to assist is in training planning and feedback process. **Chapter's 3** and **4** both identified the commonality of pre- and post-training meetings. These meetings brought together different stakeholders with physical performance data to plan and reflect. These meetings present a useful area for development of an evidence supported intervention. Physical data use can support this area by assisting in the training planning, by determining physical targets, and within post-training reports, presenting player's physical outputs and physiological responses (Nosek, et al., 2021). It is recognised however that performance practitioners do not plan and execute training sessions alone. Performance practitioners act as a member of backroom staff, advising and supporting the coaching staff who have the primary responsibility of session planning (Reilly & Gilbourne, 2003; Drust & Green, 2013; Weston, 2018; Nosek, et al., 2021). Research has also suggested that physical data in the training planning process is deemed more important by performance staff, compared to coaching staff (Weston, 2018). Therefore, it is a valuable trait of performance staff if they can offer comprehensible information within these pre- and post-training meetings to allow for coach consideration, for future training session planning and reflection.

It is imperative that the information given to coaching staff is accurate and intelligible. This can support coach 'buy-in' to the feedback process, assisting in practitioners ability to implement physical performance recommendations (Lacome, et al., 2018; Weston, 2018). Furthermore, research has emphasised the need for performance practitioners to establish relationships with other stakeholders, including coaching staff, to create trust and further enhance the ability of physical performance data to be utilised effectively (Buchheit, 2017; Ward, et al., 2019). This relationship may facilitate a clearer channel of communication with which physical performance data can be delivered to stakeholders, supporting their ability to make informed decisions.

However, previous research, and results from **Chapter 4** document a disconnect between the reporting of physical outputs, coach understanding, and the changes in practice. Most coaching and performance staff have shown that the responsibility for analysing and translating physical data lies with performance staff, indicating that simply producing physical loading reports for coaching staff is not enough (Weston, 2018). This agrees with comments made within **Chapter 4's** interviews, with some coaches preferring to be supplied with physical planning and reflective information by their performance staff, rather than seeking it out within post-training physical reports. Coaches do not appear to react to data unless prompted by performance staff. Additionally, whilst performance practitioners believe previous training load is 'very influential' in the training planning process, both coaches and performance staff agree that prior loading is only "sometimes" used to adjust training (Weston, 2018). This scenario potentially highlights physical loading reports and loading data are not understood or presented well enough to result in changes. Intuitively, this suggests that performance practitioners should simplify reports and support coaches with education to better their understanding of the presented data. This need to implement educational support for coaching staff utilising physical performance data was also recognised by practitioners within **Chapter 3's** survey.

If these concerns are actioned within clubs, this creates the opportunity for practitioners to discuss with coaches the physical demands that they would like to see incorporated within the following session(s), in addition to discussions surrounding how the session compared to the planned physical and physiological goals. By adapting the physical demands, this can ensure training sessions contain a physical stimuli sufficient enough to prompt a physiological response, a necessary requirement, as research has demonstrated the requirements for soccer players to possess an elite fitness level players (Di Salvo, et al., 2007; Bradley, et al., 2009; Andrejewski, et al., 2015). This collaboration between stakeholders should create better informed planning for training and assist in achieving the goals of fitness development and/or injury mitigation .

Whilst many decisions in physical performance/sport science are "fast" in nature, research from **Chapter 5** has produced a "slow" research outcome that will be used to inform upon current data practices (Coutts, 2016; Coutts, 2017; Malone, et al., 2019). This has highlighted that through increasing players overall total distance within sessions, a positive improvement in fitness *could* be yielded. As negative coefficient values were shown for HREx and previous fitness score, this suggested that players who already possessed high fitness levels were not being provided with a sufficient internal stimulus to promote physiological adaptation. Therefore, to modify the demand placed upon players, increased total distance and internal loading was targeted. This modified demand was due to current training potentially not eliciting the necessary physiological response for positive development to occur.

This study aimed to determine the impact of focused physical performance feedback on the training planning process within an elite soccer club. This would be implemented through simplifying training reports to focus on only two metrics (TD and HREx). Supporting these reports would be focused engagement with staff in pre- and post-training discussion, emphasising these two metrics within the planning and reflection of training. These discussion points were selected due to the frequency with which they occur in soccer, regularly seen as the most common touch point between practitioner and coaching staff (Nosek, et al., 2021). As research has also shown, successful implementation of physical performance monitoring begins with performance practitioners effectively communicating the data to stakeholders (Nosek, et al., 2021). Successful translation supports stakeholders ability to use this information to support their decision making and implement this in their practice.

6.1 Methods

6.1.1 Study Overview

This study modified the training feedback processes provided to coaching staff to support the training planning and reflection process. Insights generated in **Chapter 5** indicated the potential for the development of physical fitness to be targeted, through increased loading of two specific metrics (TD and HREx).

The study began by initially informing coaching staff of the research being conducted, and the findings from **Chapter 5**, highlighting the importance of exposing players to increased training demands to promote physiological adaptations. Following this discussion, a 3-week baseline period of normal training and feedback was conducted. Following this control period, the intervention process was then instigated.

The initial step of the intervention was a formal discussion with coaching staff, emphasising the importance of increasing player exposure to the target metrics. Within this discussion, methods of change to coaching were included. This examined how modifications to the coach’s practice could yield change to the physical targets. This followed a similar structure to behaviour change models, such as the transtheoretical model of change (TTM) (Prochaska & Velicer, 1997). Beginning with verbal discussion and the presentation of evidence was used to stimulate coaches' awareness of the issue (Figure 8). Between 'contemplation' and 'preparation', discussions with coaching staff surrounded methods to target increases in TD and HREx within sessions. Coaches presented ideas such as manipulation to common training elements, such as increasing the component durations, pitch dimensions and playing rules to target more physical demand. With support from the physical performance staff, this was discussed as to how best it could be implemented within training sessions. This then moved coaching staff towards the preparation stage of behaviour change, before implementing the informed changes within their practice.

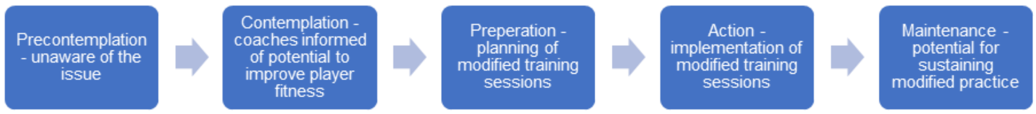


Figure 8: Example of how the TTM of change for behaviour could be applied to the intervention of coaches behaviour change.

This discussion also outlined the modifications that would occur to the feedback processes. This included a modified feedback report, presenting only player's TD and HREx from the session. The feedback process also featured pre- and post-training discussions, reflecting on loading data to continue to promote coaches awareness and understanding of the information. Data was then collected across the following 3-weeks of training. This feedback process aimed to sustain the change, as outlined in the fifth step of the behaviour change model.

Following the intervention period, analysis was conducted, comparing the average total distance and heart rate exertion for pre- and post-intervention training sessions. This was conducted to determine if the intervention had resulted in a change to physical loading within training sessions. Interviews were then carried out with coaching staff and players to discuss the impact of the intervention. This was used to detail the processes the intervention had influenced (e.g., physical demand of training demand). Ethics approval for this research was received from the University of Birmingham's ethics committee (ERN_1820-Feb2024) to conduct the intervention, subsequent analysis, and interviews.

6.1.2 Participants

Primary participants of this study were the coaching staff from an elite youth soccer club. A detailed breakdown of the coaching staff can be seen in Table 12. Eleven playing (18.9 ± 1.3 years old) staff from the same club also participated within the study. These players conducted habitual practice, having external and internal loading data collected during sessions pre- and post- intervention. Three players who had completed the highest number of pre- and post-intervention training sessions were invited to complete a post-intervention interview (Table 13). Players were informed this was entirely voluntary and could withdraw from the process at any phase, without reason. Players were notified that the study was ongoing, and its duration, but were not briefed regarding its content. This was to reduce the potential for players to regulate their physical effort in training sessions during the intervention period, due to being aware of the study's focus. Additionally, players daily tasks and responsibilities were unchanged. Whilst training was targeted to become more demanding, there was no perceived increased risk to players as all training sessions would remain within the habitual demands of soccer.

Table 12: Interview participant information documenting their position within the club, years involved in professional soccer, highest associated qualification in addition to relevant experience.

Reference Name	Club Role	Years In Professional Soccer	Highest Qualification	Relevant Experience
Coach A	Head PDP Coach	27	UEFA A Licence	Ex-professional player
Coach B	PDP Coach	12	UEFA A Licence	PhD Candidate in Coaching
Coach C	PDP Coach	38	UEFA A Licence	Ex-professional player

Table 13: Interview participant information documenting the player's position in addition to years as a professional soccer player

Reference Name	Playing Position	Years In Professional Soccer
Player 1	Centre Back	3
Player 2	Central Midfielder	3
Player 3	Full Back	1

6.1.3 Data Collection

Physical loading (external and internal load) was collected using the same methods and technologies outlined **Chapter 5**. This data was collected over a six-week period (three-weeks pre-intervention and three-weeks post-intervention). This yielded data from six pre-intervention and seven post-intervention sessions, with a breakdown of periodisation themes highlighted in Table 14. These themes were in line with the club's periodisation plan. "Extensive" themed sessions utilised larger area drills, and longer duration bouts, with an emphasis on high-speed running. "Intensive" sessions focused on small area work, focusing on increased intensity and change of direction demand. "Regeneration" sessions were those following a match day, looking to restart the player's loading training, normally lower physical demand, and greater focus on technical qualities. Finally, “hybrid” sessions contained a combination of “extensive” and “intensive” themes. These sessions were selected as they were the most physically demanding of the week. This allowed for the greatest scope to modify physical demand. Training sessions leading into matches (MD-1 and MD-2) and matchdays (MD) themselves were not included within this study due to the limitations regarding the manipulation of load possible on these days.

Table 14: Breakdown of session periodisation themes, pre- and post-intervention.

Session Theme	Pre-Intervention	Post-Intervention
Extensive	2	3
Intensive	2	2
Hybrid	1	1
Regeneration	1	1

6.1.4 Feedback Process Modification

The feedback process during the intervention period was twofold, featuring a modified digital report, in addition to formal discussion with staff to reflect upon the report and educate staff regarding the information. This ensured a constant reminder of the importance of these metrics in the effort to improve physical fitness and educational opportunity for staff. The modified feedback sheet was created exclusively for this study, using online software (Openfield Version 3.10.5, Catapult Sports, Australia). Coaches were presented with a table of total distance and heart rate exertion for all players participating within each individual session (Figure 9). Ranked bar chart figures were also presented for each individual metric to allow for a simple visual comparison between players. The modified feedback sheet differed from the normal training report provided to coaching staff, as only the two key metrics were presented. Reports during the control period presented nine metrics (duration, TD, high intensity distance (>5.5m/s), % of max speed, high intensity actions, red zone mins (>90% max heart rate), HREx and % of maximum heart rate), in addition to four ranked graphs (Figure 10).

Supporting the feedback sheet was formal discussion between coaching and performance staff. This was conducted both pre- and post-training to reflect upon session output and response, in addition to encourage continued exposure to the highlighted metrics. Within these discussions, individual responses were discussed, with emphasis placed upon individual players with the highest scoring for 30:15 IFT. This was in response to the negative relationship seen in **Chapter 5**. The physical discussion was led by the primary researcher of this study, who was also the teams physical performance coach. These meetings highlighted the sessions physical outputs compared to previous 'like-sessions' (those of the same periodisation theme) and players average values (again within like-sessions). Pre- and post-training discussions were also used during the control period (as also detailed in **Chapter 4**). However, they were not specifically focused on the exposure to the two key metrics of this study.

PREVIEW

Names Redacted	Tot Dist (m)	HR Exertion
	5760	6465
	6552	4877
	5623	6636
	5955	372
	3940	3834
	6160	11569
	5502	6831
	5353	10317
	6315	3592
	6170	9821
	5986	3009
	5698	7259
	5113	8381
	5871	8844
	5935	9486

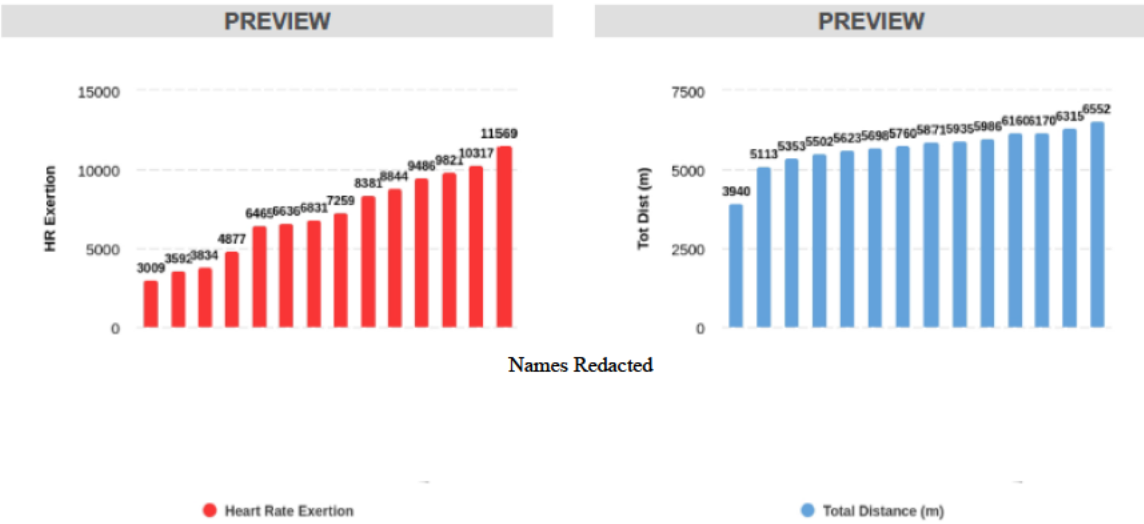
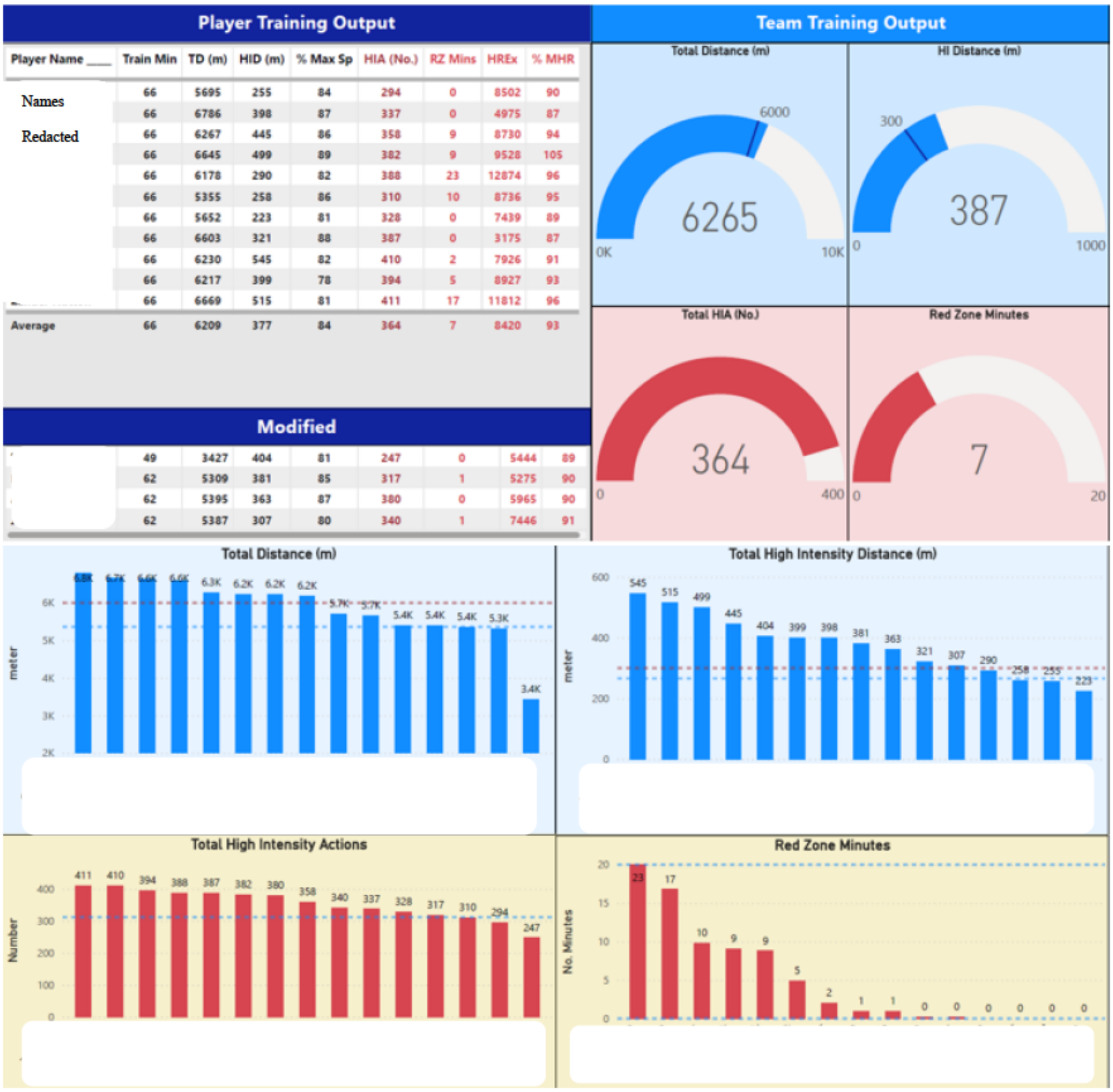


Figure 9: Post-intervention physical loading report provided to coaching staff post-training. Created using Catapult Sports Openfield (Catapult Openfield, Version 3.0. , Catapult Sports, Melbourne, Australia). Players names are redacted for data protection.



Player Training Output

Player Name	Train Min	TD (m)	HID (m)	% Max Sp	HIA (No.)	RZ Mins	HREx	% MHR
Names Redacted	66	5695	255	84	294	0	8502	90
	66	6786	398	87	337	0	4975	87
	66	6267	445	86	358	9	8730	94
	66	6645	499	89	382	9	9528	105
	66	6178	290	82	388	23	12874	96
	66	5355	258	86	310	10	8736	95
	66	5652	223	81	328	0	7439	89
	66	6603	321	88	387	0	3175	87
	66	6230	545	82	410	2	7926	91
	66	6217	399	78	394	5	8927	93
	66	6669	515	81	411	17	11812	96
Average	66	6209	377	84	364	7	8420	93

Modified

	49	3427	404	81	247	0	5444	89
	62	5309	381	85	317	1	5275	90
	62	5395	363	87	380	0	5965	90
	62	5387	307	80	340	1	7446	91

Figure 10: Pre-intervention physical loading report provided to coaching staff post-training. Created using Microsoft PowerBi (Version 2.112.603.0, Microsoft, Washington, USA). Players names are redacted for data protection.

6.1.5 Interviews

Interviews were conducted utilising the same approach, as set out in **Chapter 4** (see 4.2.7 Interview Process, Transcription, and Analysis). Coaches were asked five semi-structured interview questions, alongside six Likert scale response questions (see Appendix 5). Questions explored the perception of the intervention, alongside the impact of focused information to support decision making. The interviews conducted with players featured two semi-structured questions and two Likert scale response questions (see Appendix 6). The players interview focused upon their perception of training during the control and intervention periods. Again, the interview template was unique to this study. The interviewer was experienced in this process, with this methodology being utilised in a previous study (**Chapter 4)**. Furthermore, the questions, formatting, and incorporation of Likert scale (5-point) responses were all discussed with an experienced researcher prior to commencement of the interviews. Likert scale responses are presented as integer value alongside the qualitative descriptor associated with the mean response (Hopkins, 2010). The Likert scale used for all interviews featured the following verbal anchors (1 – strongly disagree, 2 – disagree, 3 – unsure, 4 – agree and 5 – strongly agree). These ascending, equally spaced anchors were used due to their extensive use in research, and to avoid potential response order effects (Chyng, et al., 2018).

6.1.6 Statistical Analysis

Physical loading data was analysed using specialist statistical software (IBM SPSS Statistics, version 29, IBM, New York, USA). Differences in mean pre- and post-intervention total distance and heart rate exertion values were calculated using an independent samples t-test, across all session types, with statistical significance set at <0.05. The magnitude of these differences was assessed using Cohen's effect sizes (d), using threshold's set out in the supporting literature (<0.2 *trivial*, 0.2 to 0.49 *small,* 0.5 to 0.79 *moderate* & >0.8 *large*) (Cohen, 1988). Due to the small sample size of sessions pre- and post-intervention, Hedges' *g* was also calculated (Lakens, 2013; Lin & Aloe, 2021). Likert scale questions were averaged and presented by the mean integer values associated descriptor (Hopkins, 2010).

6.2 Results

6.2.1 Physical Loading Impact

Players completed on average five sessions (± 1) pre-intervention and five sessions (± 2) post-intervention. Players completed a similar number of each session type within the club's periodisation strategy (e.g., extensive, intensive). This ensured players were not exposed to a significantly different number of session type pre- or post-intervention, potentially biasing results.

The feedback intervention created a significant change in physical outputs ($p < 0.01$; $d = 2.1$). Heart rate exertion changes was deemed non-significant ($p = 0.09$; $d = 0.97$) per session. These changes, seen in Figure 11, were calculated across all session types, pre- and post-intervention. These changes were considered *large* in magnitude-based inference (>0.8). When hedges' *g* is used to account for the small sample size, both values still return *large* effect sizes (total distance $g = 1.95$; heart rate exertion $g = 0.90$) (Lakens, 2013; Lin & Aloe, 2021).

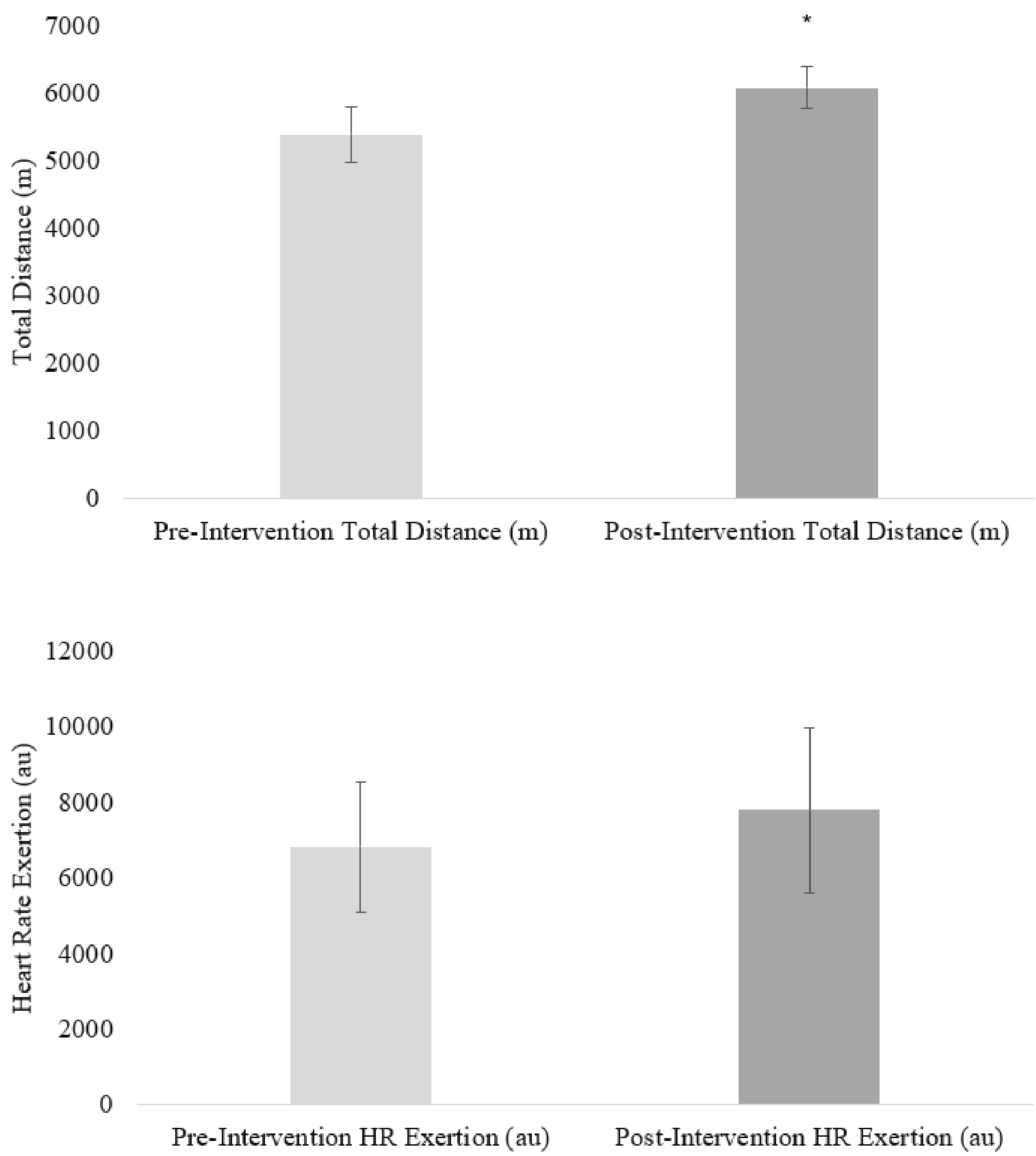


*Figure 11: Comparison of mean values for pre- and post-intervention external (total distance) and internal (heart rate exertion) physical loading values, across all session types. * indicates significant difference ($p < 0.05$).*

When examined by session types (Table 15), all session types apart for ‘extensive’, saw increases in physical loading. The large standard deviation seen in HREx values signifies the substantial variation of individual responses seen whilst collecting internal loading metrics. This is a potential reason for the lack of significant difference between pre- and post- for all session types. No further statistical analysis was conducted on the pre- and post-comparison due to the small sample size of each session type.

Table 15: Mean (± SD) values of external (total distance) and internal (heart rate exertion) loading values, pre- and post-intervention for individual session themes.

	Pre-Intervention TD (m)	Post-Intervention TD (m)	Pre-Intervention HR Ex (au)	Post-Intervention HR Ex (au)
Intensive	5338.0 (± 482.1)	6369.6 (± 356.0)	6359.0 (± 1495.9)	9301.3 (± 2482.3)
Extensive	6460.5 (± 493.9)	6419.7 (± 393.0)	7712.0 (± 2102.7)	7451.0 (± 1970.2)
Regen	3852.7 (± 420.3)	5452.7 (± 448.0)	5282.9 (± 1461.3)	7081 (± 2561.1)
Hybrid	5202.7 (± 578.1)	7174.4 (± 2093.4)	5909.4 (±261.4)	8603.1 (± 2642.1)

6.2.2 Coach Interviews

The interviews with coaching staff aimed to determine if the intervention increased their awareness of the targeted metrics. Additionally, it aimed to assess the impact of both elements of feedback. This would allow for an understanding of whether the physical report or verbal discussion provided more value in the feedback process.

Coinciding with the observed changes to physical outputs, coaching staff "strongly agreed" (4.6 ± 0.6) that they noticed an increase in the physical demand of training. Such change was likely influenced by the increased focus on the target metrics. Coaching staff "agreed" (4.3 ± 0.6) the meetings increased their awareness of the physical loading metrics.

Determining which aspect of the feedback intervention was most effectiveness was a key aim of this study. Staff were asked to assess the level of agreement to two statements, highlighted in Table 16. Staff "strongly agreed" that both elements of feedback were beneficial to developing their understanding. All three staff rated both elements equally (4.6 ± 0.6), indicating that there was no specific element that presented the greatest developmental assistance.

Table 16: Coaches responses to Likert Scale questionnaire regarding level of agreement regarding the benefit provided by both the verbal discussion, and physical report, on their awareness and understanding of the physical needs for performance improvement . (Likert scale: 1 = Strong Disagree, 2 = Disagree, 3 = Undecided, 4 = Agree, 5 = Strongly Agree)

Likert scale response questions	'You found the verbal discussion beneficial to increasing your awareness and understanding of the physical demands required to increase performance.'	'You found the physical report (containing the two metrics) beneficial to increasing your awareness and understanding of the physical demands required to increase performance
Coach 1	5 (*strongly agree)*	5 (*strongly agree)*
Coach 2	4 (*agree)*	4 (*agree)*
Coach 3	5 (*strongly agree)*	5 (*strongly agree)*

The interview questions also highlighted this feeling that both feedback methods were required for the success of the intervention. All coaches believed that the best approach was "a combination of both" (Coach C). They felt that both elements allowed you to see (report) and understand (verbal) what players had done. It "made sense" to receive both, as the written report "backed up" what was being said during the discussions. Coach B agreed that the feedback brought "clarity" of understanding as to what the players were doing within training, and it assisted in achieving "an increase in physical outputs".

Regarding the benefit brought by the individual elements of feedback, the report allowed coaching staff to:

"reflect and compare scores easily" (Coach B)

However, in isolation, Coach C stated that they would "struggle to understand it". They did however stress their desire to comprehend this information through learning, to allow them to discuss the data with players. This is where the verbal discussions became valuable:

"when we speak about it, why we do it…that gives me a clear focus" (Coach C)

Verbal discussions were used to educate staff on the physical outputs and explain the reports. This allowed the staff to develop a similar understanding to performance staff:

"I can now speak about the data clearly…my interpretation of it is now similar, or the same to what you guys (performance staff) are speaking about" (Coach C)

The coach felt this was also important, as if the playing staff recognised that the coaches also understood and valued the importance of the physical demands and physical outputs, they knew they had to put in the "effort" and "application" to training.

The final area of exploration was to document how the intervention altered the coach's approach to training. All coaching staff recognised that manipulation of duration was a vital component. They commented that the length of individual activities and work rate was sustained for "longer". Coach B noted that this was completed through several modalities:

"adding phases for example extra balls, repetitions or time scale to increase the duration of an activity" (Coach B)

Coach A also noted that not only extending the duration of activities, but reducing the time spent between them was also a method employed to increase the physical demand:

"being really big on less down-time" (Coach A)

A final point made by Coach A in relation to the intervention highlighted the impact that physical performance data can have upon the practices of an experienced soccer coach and a club's training philosophy:

"probably one of the best interventions to get an overall development…I can't see why we wouldn't continue to use this going forward" (Coach A)

6.2.3 Player Interviews

Players were interviewed to assess if they were aware of the impact of the intervention upon the physical demands, coaching approach, and session style of training sessions. They "strongly agreed " (5.0 ± 0.0), that training sessions during the intervention period were physically more demanding. Players also recognised the methods of training modification implemented by the coaching staff. All players commented on the reduced rest period between training components, and longer time spent within drills. Player 2 commented that the recovery periods "were quicker", with Player 3 echoing this by noting "there is less…time to stop". Players also felt that the changes incurred due to the intervention elicited a response in the intensity of training. Comments surrounding "*higher intensity"* of training was made by Player 1, with Player 2 feeling this elicited a higher standard within training.

6.3 Discussion

Using evidence obtained through an investigation into collected physical performance testing and loading data (**Chapter 5)**, the physical performance feedback process of a professional academy soccer team was adapted to drive focus on two metrics. The increased focus on two physical metrics through discussions with coaching staff and a modified training feedback sheet resulted in changes to the physical demand of training sessions. These were identified through a significant increase in total distance covered per session. Additionally, non-significant, but *large* increase in heart rate exertion were also recorded. It also elicited changes in coach's and player's perception of the physical demands of training. Coaching staff identified that the integration of both the verbal discussions and written feedback was crucial to the informed decision-making processes. This study, whilst simplistic in approach, highlighted that (a) physical performance data can be collected within a club, (b) analysed to create a focused and impactful feedback process, supported through the education of coaching staff, to (c) successfully yield changes in practice.

The intervention of modified feedback was effective in producing a change in physical loading experienced by players during the sessions. Pre- and post- comparison highlighted an increase in session outputs. Total distance increased significantly, with heart rate exertion also increasing across all sessions. The change to practice stemmed from an increased focus of physical performance data supplied by performance staff to the coaching staff. **Chapter 4** research had already highlighted that a common touchpoint between coaching and performance staff was pre-training and reflective post-training meetings. This agreed with previous literature (Nosek, et al., 2021). With this understanding, the modification of the feedback process utilised these discussions to implement the integration of novel data-backed feedback.

The intervention featured two modifications to normal practice. Interestingly, subjective qualitative feedback suggested both elements of the feedback process (physical loading reports and verbal discussions) were valued with equal importance. Verbal discussions educated staff on the physical outputs, whilst the reports backed up what was discussed. One coach stated, *"when we speak about it, why we do it…that gives me a clear focus"*, whilst both coaches felt that the data "backed up" the points discussed. Both research in **Chapter 4** and previous literature suggested that the production of physical loading reports alone is unlikely to prompt change in coaching behaviour (Weston, 2018). This may be due to coaching staff indicating that the responsibility of translating physical loading information lies with performance staff. A limitation of this study is that it did not assess the impact or process of coach understanding in relation to the two elements of feedback. Whilst both were viewed as important, understanding the individual processes specific to both methods that supported change in the coaches practice would be of benefit to future intervention practices.

This translation of information is an important skill for performance staff have. This also necessitates the development of trust and buy-in of the coaching staff with the information they are being delivered. Whilst coaching staff are aware of the physical data, there may be a lack of understanding, or willingness to engage unless otherwise encouraged by performance practitioners. As such, the creation of trust and a bond between performance staff and coaching staff may facilitate better communications and resultant engagement with the data (Buchheit, 2017; Ward, et al., 2019). If this is established, feedback will likely become more effective (Buchheit, 2017). As the practitioner providing feedback within this research had worked with the coaching staff prior to the study, this relationship was pre-existing. This potentially contributed towards the success of the intervention. With the ability to freely communicate with coaching staff, and where trust is evident, discussion and action with support of the key metrics can occur.

Supporting the verbal discussion was a modified physical loading report. The layout of physical performance reports has also been highlighted as important when attempting to drive coach "buy-in" (Lacome, et al., 2018). It has been suggested that improved visualisation of data could "improve their ability to make informed decisions" (Lacome, et al., 2018). As highlighted in Figure's 4 and 5, the modified feedback reduced the volume of data presented and highlighted the key message of the intervention. Additional 'noise' was removed from the report, and information was presented in simple graphs. Both elements have been highlighted as supporting effective report feedback (Buchheit, 2017). This decrease of overall information and increase of specific and relevant data may have improved coaches understanding of the outcomes being targeted. Together, this two-pronged approach was successful in implementing modified physical performance data into the coach's decision-making processes. This was assessed by the alterations to training session outputs.

The approach used increased awareness and elevated prominence of the target physical metrics resulted in adaptions to the coach's session delivery. This was seen through increasing the duration of session components and reducing the rest periods within the session. These changes were documented by coaching staff during the interviews. Coaches noted the inclusion additional elements within a drill *"for example extra balls, repetitions or time scale to increase the duration of an activity" (Coach B).* Players identified these changes also, commenting that the *"gaps between drills were quicker"*, emphasising the increased work to rest ratio. This concept of increasing work periods, and/or reducing the rest period is extensively researched and shown to be an effective method of altering physical demands (Owen, et al., 2012; Owen, et al., 2014; Clubb, et al., 2022).

One session type however remained unchanged by the intervention. Results showed no change to 'extensive' session physical demand. This is possibly due to it already being the session type producing the highest physical outputs. This may have limited the scope of adaptation that could occur within the session planning.

The final comment made by Coach A emphasised the impact the intervention had upon their coaching practice. Returning to the TTM, this suggests the coach had entered the 'maintenance stage' whereby their behaviour had successfully been changed (Prochaska & Velicer, 1997). The modification to feedback resulted in changes to training planning, which in turn they believed supported their player development process. As such, the desire to ensure this approach was maintained was evident. This point, whilst not directly related to the purpose of the study, emphasises the ability of data to stimulate change. The recognition of a possible area of development has ultimately resulted in the change to a coaches approach to planning and delivery of training sessions.

6.4 Conclusion

This intervention has identified that physical performance data can be analysed to find informative insights, translated to stakeholders, and used to inform the decision-making process surrounding training planning. Previous research and interviews with coaching staff suggest that the use of one feedback method alone does not appear enough to stimulate changes in coaches practice, whereas the combination of written and verbal feedback serves to concomitantly educate coaches, whilst providing evidence to back up the discussion. Future research examining these interventions in isolation, and in combination, would be considered beneficial to understanding how impactful this combination approach really is. It must be stressed that a recurring theme surrounding the lack of effective implementation of information lies in practitioners ability to effectively communicate with stakeholders (Nosek, et al., 2021). Failure to do so may result in misunderstanding, and a lack of informed decision making to drive change.

CHAPTER 7:

SYNTHESIS

7.1 Summary of Findings

This research project aimed to present findings regarding physical performance data use within soccer clubs. The research structure utilised supports the advancement of understanding in this area by presenting in detail, the structures supporting data monitoring practices, in addition to the processes of data collection, analysis, feedback and use. This rounded view allows for a greater appreciation of the complexities and considerations for effective data use in soccer. This thesis also spans the applied research model for sport sciences (ARMSS) (Bishop, 2008). Beginning with a general approach of physical performance data practices across elite soccer clubs, this defined some of the issues related to physical performance monitoring. The following research phase narrowed to focus upon the processes of how this data is used to support practice within a single club. This one club approach allowed for a high level of descriptive research and detailed understanding of data practices. Utilising the findings from both this study and the initial research, areas of inefficiencies were identified and the processes that could be targeted to improve upon them pinpointed. This resulted in a final study implementing an intervention to assess the impact of data informed feedback upon player development. The overall approach of the research aimed to expand knowledge in this area by providing evidence to support good-practice, and ultimately, demonstrate that data can be used to influence decision making.

These closing sections will serve to reflect upon the aims and objectives of the research project and synthesise the individual study's findings. This will integrate the results from the broad initial studies to the focused methods of enhancing the state of current monitoring in elite soccer, and how they link to enhance our knowledge of physical performance data.

7.1.2 Achievement of Aims and Objectives

The principal aim of this research project was to critically analyse the impact and influence of physical performance data in the support of physical development in professional soccer. To achieve this primary goal, several objectives were set to provide a progressively more detailed approach of investigation. This examined how the physical performance monitoring structure currently exists, and methods to improve upon this to further the support offered by performance practitioners. The initial objective was to "*Describe and evaluate the organisational structure and the collection, processing, and use of physical performance data in professional soccer clubs*", covered in **Chapter 3.** This multi-club, expansive study established the physical performance monitoring landscape, through its use of an online participant completed survey to engage with a high number of participants, illuminating the practices and beliefs of practitioners across Europe. Practitioners in professional soccer clubs collect a multitude of information, across many areas of physical performance. Most of these practitioners report a positive use of data, with the belief they achieve a good return on investment. However, inefficiencies with the data process exist. Many clubs operate without appropriate staffing or monitoring structures in place. This likely results in ineffective data practices, including the collection of redundant data. Additionally, performance staff have expressed that greater "buy-in" by staff and education may support more impactful use.

The following objective narrowed the focus of monitoring performance data to examine the "process and the rationale that drive data collection, processing, and use of physical performance data in an elite academy soccer club". Research in this chapter built on the data landscape by adding context to data use, by utilising an elite academy team as an 'example' club. This was completed in **Chapter 4** through the undertaking of a novel multi-modality study to understand the interaction between stakeholders involved in the player development pathway, and physical performance data. Research highlighted data collection practices used to support player development decision making. Common touch points used to share this information included pre- and post-training discussions, in addition to the use of digital reports. Use of this information varied between stakeholders, with coaching staff highlighting their desire to be informed of important findings from physical performance data. A main finding emphasised the importance of strong and trusting relationships between coaching and performance staff to facilitate the effective use of data. Again however, inefficiencies were present, such as the volume of data collected compared to use, with the production of physical reports that were not engaged with. Overall, this study established the processes with which data is used within an elite soccer club, allowing for the identification of areas for possible intervention. This allowed the following objective to be targeted within the final phase of the research project.

This final phase aimed to identify informative insights from physical performance data and implement it into feedback processes, within a single club. **Chapter 5** initiated this phase through its objective to "explore the relationship of physical performance data to evaluate the development of focused data feedback and use". Statistical analysis was conducted to determine informative insights from the relationship between physical loading data, and changes to physical capacities. This was completed with the aim of producing focused data-backed feedback for the purpose of physical development. This analysis identified two key metrics with an associated relationship to the potential improvement of physical fitness, as assessed by 30:15 IFT physical performance. These two metrics were then used to implement a focused and meaningful data feedback process, aiming to improve the effectiveness and efficiency of data monitoring effective within the final chapter.

The final objective was to “ assess and evaluate the potential for an evidence-informed data use strategy to influence changes in the planning of physical performance development”. By adopting a novel feedback process, utilising the two key metrics identified in **Chapter 5**, an intervention study was conducted. This involved the delivery of a modified post-training report to coaching staff, reducing the metrics presented. In addition, formal discussions were conducted to educate staff on the importance of these metrics and support the understanding of the new reports. This intervention produced *large* changes in physical outputs and response to training sessions, compared to pre-intervention. Coaching staff recognised the benefit of both methods of feedback, highlighting the requirement of both understanding, and seeing the data. **Chapter 6** demonstrated the ability of a data-driven feedback process to impact the practices of an elite youth soccer club.

7.2 General Discussion

This thesis presented several key findings regarding the structure and use of data within soccer to support physical performance. These findings should contribute to the development of the theory, methodology, and practice associated with physical performance monitoring within elite soccer. Due to the applied nature of the research, many of the findings support the development of wider practices across soccer.

The purpose of physical performance monitoring within elite soccer

Soccer has experienced a rapid growth in the support provided to players. Staffing structure has grown from primarily coaching staff only, to entire backroom departments, tasked with ensuring players are in the best possible condition to compete and bring success. As part of this growth, performance staff have become a staple member of the backroom team, focused on the physical component of a player’s performance. These staff, aided by technological advancements, now operate extensive monitoring to gain insights into their player's physical profile (Malone, et al., 2020; Almulla, et al., 2020; Evans, et al., 2022). This research has clearly indicated that soccer club's collect a wealth of information on their player's physical profile to support two key objectives, identified within **Chapter 3**. The development of physical qualities and the mitigation of injury risk are ranked as the most common purpose for monitoring player's physical performance. The literature highlights the importance of both areas, with the physical ability of players a component of successful performance (Arnason, et al., 2004; Lago-Penas, et al., 2010; Lago-Penas, et al., 2011; Owen & Dellal, 2016), and the reduction of injury risk likely supporting enhanced team performance (Arnason, et al., 2004; Eirale, et al., 2013; Hägglund, et al., 2013). The alignment of teams towards prioritising one of these objectives was seen to be related to the age grouping of the squad. Academy squads leaned towards monitoring for performance enhancement, with senior soccer teams prioritising injury mitigation. This orientation towards performance enhancement was also seen within the intervention, aimed at improving physical fitness of elite academy soccer players. As academies act to prepare young soccer players for a transition into senior squads, the focus and monitoring of physical enhancement is an important process step (Elferink-Gemser, et al., 2012; Mills, et al., 2012; Raya-Castellano & Uriondo, 2015; Morgans, et al., 2022).

Despite this age-based preference, the development of athletic qualities should not cease to be a priority when player's transition to senior soccer. Whilst the mitigation of injury risk is important, it is possible that this objective may also be supported by the enhancement of player's athletic profiles. Matched with expected increases in the physical demand of soccer, practitioners should also be challenged to continue to develop their athletes. Similarly, time-loss injuries to young players have been shown to reduce the likelihood of successful transition to senior soccer (Larruskain, et al., 2022). Therefore, it may be an important consideration for youth practitioners to amend monitoring practices to increase their focus upon injury mitigation.

Whatever the preference, the development of a priority objective of monitoring is a focal consideration for practitioners, who must assess their desired use of performance data before initiating data collection practices. This should support a better-informed selection of monitoring and technology, targeted towards their specific overall objective, thus improving the support this data can provide.

<u>Data collection practices within professional soccer</u>

Whilst research has exhibited the wealth of data that is currently collected by practitioners, these have been restricted to the examination of individual facets of physical performance (Akenhead & Nassis, 2016; Asimakidis, et al., 2024). **Chapter 3** presented the breadth of data collection within professional soccer, evidencing data collection across ten different areas of performance. Soccer teams collect a range of data points regarding, but not limited to, player physical loading, wellbeing, player's biochemical markers, in addition to testing their performance capacity. **Chapter 4**'s club-based approach allowed for more detailed evidence to highlight this extensive data collection within a single team. Within the observed club, data was collected across multiple areas of physical performance, yielding more than 140 different metrics being collected, per player. With such an expanse of monitored areas across all clubs, this metric count from the sample club may present only a modest value.

One element that this research did not explore in detail was the range of technologies currently in use. This may have provided a greater understanding as to the variety that may exist in soccer. This further emphasises the complexity and diversity that exists in monitoring practices. However, it is recognised that monitoring practices and technologies are advancing at high speed. This means that many trends and methods of monitoring may quickly become obsolete. This is due to emerging technology and a greater appreciation of the role data can play in supporting performance. New technology will likely present a greater expanse of metrics, with many "brand-specific". This could further impact upon the clarity of monitoring by creating a more complex data landscape. Where clubs are not prepared with suitable processes, there may be a negative impact to the efficiency and effectiveness of their data monitoring. **Chapter 3** highlighted this possibility. Results demonstrated the vast quantity of data collected, high levels of data redundancy, in conjunction with few data specialists, and convoluted data processing methods.

Whilst the survey (**Chapter 3**) allowed for a general overview of data collection Practices within professional soccer, the single club analysis of **Chapter 4** allowed a detailed depiction of this collection in action. Much of the data was collected most of the time. Load monitoring and wellbeing data were the most frequently collected, agreeing with **Chapter 3**. Collection trends showed that training days had the most physical elements being monitored. The use of 'live' data collection, such as load monitoring also presented a novel finding. This demonstrated the possibility of technologies now at the disposal of soccer teams. However, what was apparent was the low use of this data to warrant action, in relation to the amount of information collected. This finding could be viewed from different perspectives. First, the lack of action may present a training and player development strategy that requires minimal response, as it is effective in progressing player development, whilst minimising injury risk. This is likely seen in the lack of post-training meetings using physical loading reports to adapt following sessions. Pre-planning of sessions and 'live monitoring' likely results in little deviation of expected physical outputs. In turn, this means that the solitary change to loading planning based off post-training reports should be expected. The low actions resulting from data collection may also be indicative of a lack of specific and detailed analysis. Findings may not be sensitive enough to determine key findings, resulting in little or no change to practice. This itself warrants further investigation. There also exits the possibility that the low use resides within the support given by other practitioners. Results from this thesis have clearly highlighted that "buy-in" from other staff is vital in attaining positive data use within soccer clubs. Data use could be low simply through other staff showing no attention to data, or not trusting the data provided. Conversely, staff may be willing to interact with data, however, it may be their understanding that ultimately limits use. Whilst this lack of understanding will be explored further within this synthesis, it is paramount that practitioners and club's assess their data efficiency. Only by identifying the issues, can development of the overall strategy progress. Whilst this research has examined the efficiency of an 'example' club, more work to detail efficiency at each stage of the monitoring process would be beneficial.

Due to the expanse of possible physical components that *can* be monitored, and technology that now exists, it is an important consideration for practitioners to determine which areas will support their monitoring objective. This expands upon the initial discussion point encouraging practitioners to develop their purpose for monitoring. The development of objectives to support this overall purpose is key to allowing detail to be added regarding the specific methods and metrics will facilitate this. This was seen within **Phase 3's** intervention approach. 'Slow' research was used to determine insightful metrics to achieve a specific purpose. When incorporated within a targeted intervention, exploiting the frequent collaborative meetings, and the education of staff, positive outcomes were achieved. This narrowed use of data for a purpose should be adapted by practitioners to improve both the efficiency and efficacy of their monitoring work.

Supporting framework of physical performance monitoring

With the understanding that physical performance monitoring involves a vast amount of data, with the potential for this to increase, it was considered necessary to document that framework that supports these processes. Data monitoring processes include the collection, processing, feedback, and potential use of this information. This operation requires relevant understanding of the technologies and methods used to harvest the information, knowledge of appropriate statistical methods to best analyse the information, and the ability to present information in a clear and comprehensible manner to inform relevant stakeholders. Despite these demands, it was revealing to discover that only around a quarter of surveyed professional clubs operated with a dedicated data specialist. Research would suggest that the level of skill and understanding to operate high-level data processing and analysis would necessitate the inclusion of such a staff member (Rein & Memmert, 2016; Rojas-Valverde, et al., 2019; Newell, et al., 2022). This likely means that the responsibility of managing the data processes falls upon a practitioner with other responsibilities. This rightfully questions the efficacy of data processes within clubs. Whilst many staff are likely proficient in data collection, analysis, and producing feedback, this lack of specialist staff to deal with data, potentially dilutes the quality performance practitioners tasked with other roles, such as physical development. With practitioners already feeling the stress/strain of managing the physical component of their player's development, therefore the additional workload potentially related to data will not act to alleviate this (Malone, et al., 2018). This issue may have arisen due to the speed at which monitoring technology has advanced, catching some clubs unaware. This concept of detailed player monitoring is still relatively new, especially at the level of monitoring that is currently being conducted. As such, clubs may not be fully aware of the staffing investment also required to support these practices, or the burden currently faced by their practitioners.

Supporting the staffing structure is the use of appropriate data storage and processing methods. When done appropriately, this can effectively house large volumes of data and allow for the application of suitable analytical measures. Together, this can result in informative insights. Research has highlighted that data storage and processing at most clubs using multiple software tools, with many lacking a centralised system. This likely leads to data silos, where information is not able to be viewed together. These findings are important, and vital that its impact is understood. This is as many clubs may continue to invest in technology to gain greater insights into their players, without establishing appropriate data handling and analysis methods. This in turn may limit the insights that can be gained through technology. This finding is also backed up by recent research, showing that many practitioners are still utilising simplistic software, not suited to the high level of data and associated analysis required for professional soccer (Asimakidis, et al., 2024). This finding is shared when exploring the analytical methods collected from **Chapter 3**. Many of the processes currently operated likely do not consider individual differences, and very few practitioners listed measures to account for variation within measurements or performance (Ward, et al., 2018). It is not possible to ascertain from the current research, however, it is conceivable that the lack of specialist data staff within club's may be a contributing factor towards this finding. Clubs are potentially relying on performance practitioners who do not possess the knowledge to use advanced analytical software and analysis processes.

Whilst this research (**Chapter 3**) and recent work (Asimakidis, et al., 2024) have explored both the macroscopic level and individual areas of physical performance data storage and analysis processes, more work is still required to produce recommendations for practice. Moving forward, it would be deemed advisable that soccer clubs operating with monitoring practices conduct thorough reviews of their practices and supporting structure to ensure relevant people and systems are in place. Whilst many clubs are eager to invest and expedite the introduction of technology, they must ensure it is introduced on solid foundations. The importance of skilled staff who can effectively process and analyse the data must also be valued by teams moving forward, alongside suitable data management systems. A lack of a sufficient supporting structure may limit the efficacy of data use. As technology continues to advance and become even more accessible, this may further increase the magnitude of these concerns. Further research directed towards storage and processing practices would be extensive and extends beyond the scope of this general research project. This is an important area of consideration due to the expectation that soccer monitoring will continue to expand, advancing in its use of "big data", machine learning and resultant implications to storage of personal data and related accessibility issues. It is likely that many of these factors are not currently under consideration by soccer clubs. Whilst performance practitioners may be able to support such processes and advances, it is unlikely they will be able to provide a quality output, if balanced with other tasks.

Inefficiencies of data monitoring practices

Despite three quarters of performance (73.2%) practitioners believing data supported their objectives, and 69.8% of practitioners believing they achieved positive return on investment from monitoring, concerns with current practices were identified. **Chapter 3** identified the overcollection of performance data, resulting in information redundancy. Whilst many areas presented reasonably efficient values, such as over 80% of practitioners using 'most' to 'all' of their collected external load monitoring within further processes, other areas were highly inefficient. 22.6% of respondents estimated their use of this data was 'none to very little'. Where data is collected without purpose, resources may be wasted, impacting the club overall. This inefficiency may be indicative of a lack of specialist staff. Such refining of data practices to reduce such waste may only be possible by staff fully engaged with the information.

Chapter's 4 and **5** also identified evidence of this inefficiency. **Chapter 4** documented the high level of data collection in comparison to action taken. With over 140 metrics being collected, it is worthwhile identifying those that provide the most impact to monitoring to improve efficiency. This was extended within **Chapter 5**. This highlighted that relationships between data can be maintained, even when fewer metrics are included. The reduction of six loading metrics to two produced very little reduction in the relationship between physical loading and changes in fitness testing. This emphasises the need for practitioners to understand the information they are collecting, and what it *actually* tells them. This research may open an avenue for future investigation into the establishment of meaningful metrics. This may reduce the overcollection of data and streamline the metrics currently in use within professional soccer. Both **Chapter 4** and previous research (Akenhead & Nassis, 2016) highlighted this abundance of data, agreeing that over 50 metrics associated with physical load monitoring are currently collected. Practitioners should ensure they collect the right amount of data for purpose. This should improve the efficiency of collection of data.

Within the feedback process, performance staff believed data use was sometimes hampered by coaches lack of understanding of the data. Practitioners also noted a lack of "buy-in" to data, with the need to "educate" staff further to support the development of performance monitoring within their club. Coaching staff were viewed to be passive in the monitoring process, with a preference to be informed of physical insights. Practitioners believed that "greater education around metrics" was needed to improve the effectiveness of data use. Six practitioners also highlighted that data was not always valued by other staff. **Chapter 4** results showed coaches reluctance to engage with the post-training physical reports, and technology such as live monitoring tools. Whilst this is not entirely necessary to support training practices, it may be an indication that staff require greater educational support to better understand these practices. It may also suggest that staff do not care for the information, either through a lack of knowledge as to how it can support their practice, or simply not liking data. Whilst within this chapter it was considered positive that coaching staff "trusted" their performance practitioners to inform them of key physical insights from training reports, the findings did question the purpose of producing reports for staff. By educating staff, more collaborative discussions may evolve, resulting in positive outcomes. Staff may also become more 'active' to data and begin to comprehend the information contained in reports and feedback prior to discussions with their performance staff. This could allow performance staff to discuss physical concerns on a deeper level with coaching staff. It is understood that these reflections represent a small sample of staff within a single club. However, owing to the extensive and varied experience of the staff across their professional careers, in addition to the overlap between many of the comments with those provided by practitioners within **Chapter 3**, it is believed that this ‘example’ club provided a suitable representation of the current coach beliefs within soccer.

The intervention aimed to challenge this through adaptations to the feedback process, centring around coach education and use of a more insightful data set. The results from the final chapter demonstrated that such a simplistic report, supplemented by discussion was impactful in instigating change to practice. Whilst it is known that feedback should be comprehensible (Buchheit, 2017; Lacome, et al., 2018), these findings confirm that less, can be more. The use of complex data presentation may be suitable within the performance department, where the data is routinely handled and understood. However, knowledge of this data should not be presumed of other stakeholders, especially when attempting to communicate key messages. As stated within this thesis, “technology does not inherently communicate a message” (Windt, et al., 2020). Practitioners should consult with the stakeholders who these reports to ensure that effective translation occurs. This feedback process may not only act to improve the interpretation of this information, but also improve stakeholder ‘buy-in’, by including them within the design process. By contributing towards the report process, they may in turn be more willing to engage with the data.

<u>Data use within professional soccer</u>

Research within **Chapter 3** documented an overview of data use within professional soccer. Results indicated that this data was used to support many decision-making areas, with 75% of clubs often using physical performance data to determine player’s training load, and over 80% using collected data to determine physical development objectives. The results also identified that this information was regularly shared between stakeholders within regular meetings. Only 6.3% of performance practitioners stated they 'never' or only 'frequently' discussed physical performance data with other staff. These outcomes are supported by previous literature, highlighting the use of performance data in soccer (Kelly, et al., 2020; Hostrup & Bangsbo, 2022). Using observations and interviews, **Chapter 4** expanded upon the understanding of data use by documenting occurrences and providing contextual information.

A key element of the training day was the pre-training planning meeting, where historical physical loading and wellbeing data was presented and discussed, informing upon player's training involvement and targets. Ensuring players are in a 'ready' state to train is important to support the aim of injury mitigation, whilst target setting and manipulation of load is important for supporting physical development (Noon, et al., 2015; Heidari, et al., 2019; Falch, et al., 2019). Whilst data collection and use highlighted that wellbeing data was gathered and presented every training day, the exploration of action taken showed that changes to player's loading or involvement within the session occurred on 27.8% of training days. This demonstrates the importance of understanding the terms of data feedback, use, and action. This example highlighted that whilst data was 'used' every day, it does not always result in an action.

Data was also monitored during both training and match play, through the collection of physical loading information. This data, relating to player's activity and response allows practitioners to ensure players are hitting physical targets to support physical development and reduce the risk of inappropriate physical loading (Gabbett, 2016). Emerging technology such as real-time monitoring was observed in use, with performance practitioners utilising this ‘live’ information to inform upon pitch-based decisions. Whilst coaches were reluctant to use this information, and players were not consulted, scope for future implementation into practice exists (Catapult Sports, 2022; Asimakidis, et al., 2024). These emerging technologies may require educational support, a recurring theme of the thesis, to be provided to coaching staff to develop ‘buy-in’ and comprehension of what the data is showing. Data was shown to be involved in longer term decision making too, such as by providing updates on player development updates, and supporting talent identification. This longer term, strategic use was also presented within **Chapter 3**. Over 37.% of clubs ‘often’ or ‘always’ used physical performance data to support talent identification. Conversely, 39.6% ‘rarely’ or ‘never’ used this information for this purpose. This finding highlights the varied use of physical performance data, likely dictated by staff experience, understanding of the data, and perceived importance of this information.

With much of the intricate detail surrounding data use being extracted from **Chapter 4**, it is important to consider the multi-modality research processes. This research method presents a complex framework to ensure robustness and validity of methods. Whilst these processes were utilised to allow for both wide-ranging and qualitative information to be collected, it is recognised that inherent limitations exist. The observational analysis presented a rare method of data collection, that allowed for the embedded researcher to present “typical” data without the sterile environment normally required for research. Whilst the advantages of this method produced some informative findings, it is recognised this research process does produce challenges. Attempts were made to reduce the risk of such concerns, outlined within **Chapter 4.**

<u>Processes supporting effective integration of physical performance data to practice</u>

A recurring theme throughout this thesis concerns the ability of performance practitioners to establish trust with stakeholders (primarily coach staff) and provide effective translation of information. Strong relationships are seen to strengthen the ability of practitioners to communicate actionable information to support the aims of development and injury mitigation. This has been discussed in both previous research (Buchheit, 2017; Lacome, et al., 2018), and within staff interviews in **Chapter 4**.

Research has emphasised the importance of such relationships and communication in football (McCall, et al., 2016; Buchheit, 2017). Supporting this belief in the importance of relationships and the ability to communicate information clearly and effectively is the results of the **Chapter 6** intervention. The results yielded clear evidence supporting the use of simplified and educational feedback, providing coaches with both the training outcomes, and the assistance to help understand the data/physical demands. This two-pronged approach was effective in implementing the desired physical change to practice. Whilst the effectiveness of this intervention upon the physical qualities of players was not measured, nor the impact of the individual feedback processes, the results clearly showed the importance of effective communication. This finding extended views from previous research, that intimated such changes would be beneficial to the approach of practitioners (Lacome, et al., 2018; Nosek, et al., 2021).

Whilst this research demonstrated that a dual modification to the feedback strategy could educate staff, and stimulate changes to training, the approach taken assessed the impact of these feedback methods simultaneously. Research to isolate the individual impact of both feedback methods would have proved beneficial in establishing the efficacy of both elements, and when combined. The current study methodology makes it difficult to ascertain this outcome, and it is proposed that over time, coaching staff may better comprehend the written reports, therefore rely less on the verbal discussions. However, owing to the result throughout this thesis, it would be suggested that (a) the development of strong relationships with coaching staff is established. This would (b) allow for the education surrounding the importance of performance data to (c) support the feedback and use of data by all stakeholders in the player development process.

General Discussion Summary

The discussion has aimed to detail the findings of the research, in addition to expanding the scope of conversation beyond that of the individual chapters. This incorporates areas of practical recommendations and limitations of the research. With areas of concern being raised, it is deemed worthwhile summarising the key practical recommendations raised within this section. Table 17 highlights these suggestions. These aim to detail the key points that are deemed most significant to improving the landscape of data monitoring. The knowledge gained through this thesis, using existing literature in addition to findings from the present research has been used to create a theoretical framework for data monitoring, viewed in Figure 12. The solid arrows present the typical pathway of decision making and data, with the dashed arrows indicating the areas of improvement that clubs should implement to create a more robust and effective monitoring system. The presented model contains elements of a continuous feedback loop that should allow clubs to continually refine and improve their physical performance monitoring. It is this stage that is imperative to improving current monitoring practices.

Table 17: Summary of main practical recommendations drawn from the research of this project

Area of monitoring	Highlighted concern	Attributed issues	Practical recommendation
Purpose of physical performance monitoring	Club's lacking monitoring objective	Difficult to determine appropriate monitoring strategy and technology to support purpose	Establish a priority objective for monitoring within club
Data collection and associated metrics	A wealth of information now exists, with practitioners collecting potentially hundreds of data points per player	Information overload, reducing efficiency of monitoring and clouding decision making	Narrow data collection to achieve specific monitoring objectives only. Understand the association between data and its purpose for being collected
Monitoring framework	Lack of specialist data staff	Reduced quality of monitoring processes, lacking appropriate and effective analysis. Additional potential for increased stress placed upon performance practitioners	Inclusion of data specialists within staffing structure and/or ensure data monitoring processes do not expand beyond staffing capacity
Data management and analysis software	Clubs lack appropriate software to process and analyse their information	Reduced efficiency of monitoring, inappropriate findings drawn from poor analysis, and data being stored in silos	Conduct reviews of monitoring system and implement an appropriate centralised data processing system. If required, utilise data specialists
Feedback of information and findings	Lack of "buy-in" and "understanding" from stakeholders	Data monitoring effectiveness can be significantly impacted by successful translation of information. If this is lacking within clubs, data may not action outcomes.	Ensure staff harbour positive and trusting relationships, in addition to assessing the understanding stakeholders have of the fed back information

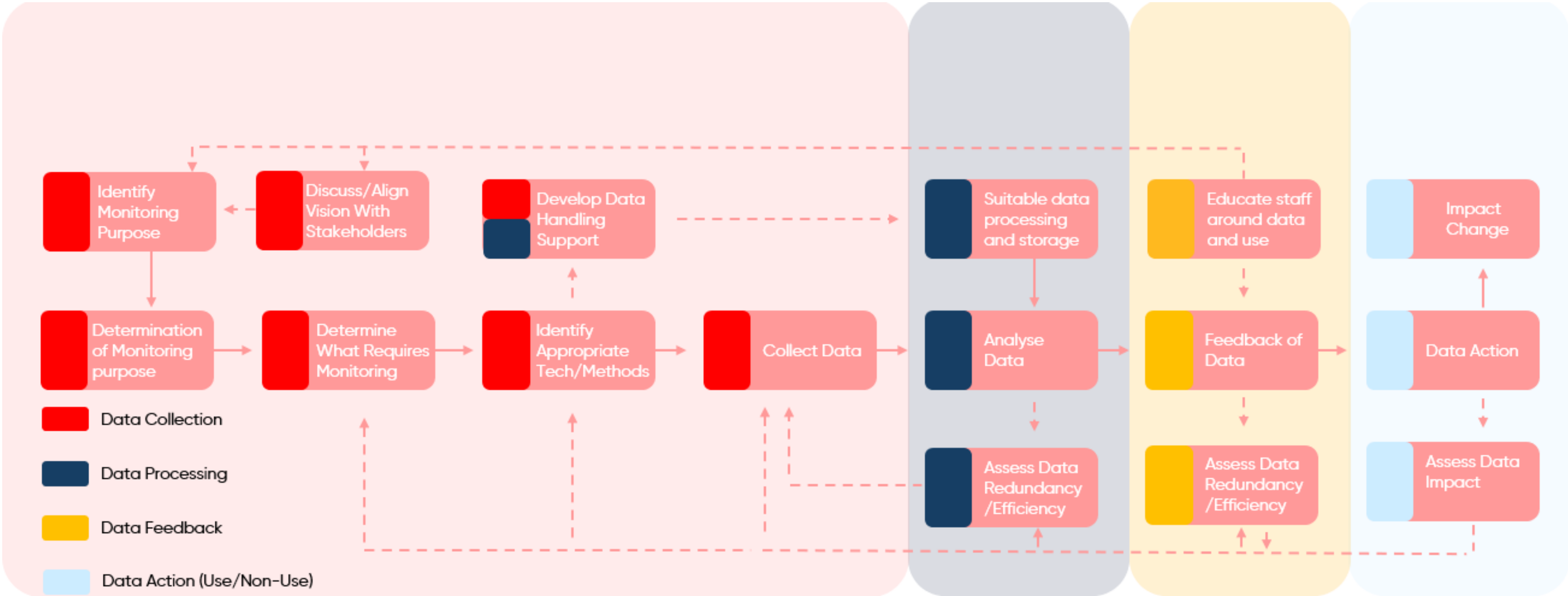


Figure 12: Proposed theoretical framework outlining the key steps derived from existing literature and current research to implement a continuous feedback process supporting physical performance monitoring. Exploring aspects of performance monitoring from collection, to processing, feedback, and use.

7.3 Future Research

Concerning future research, results from **Chapter 3** have documented the immense variability of club practices, supporting data monitoring. As such, it is important that research continues to monitor the evolution of these practices. With many concerns being highlighted, it is worthwhile documenting if work and research is impacting club structures and methods. This work should continue to support practitioner understanding and the betterment of club-based decision making, relating to improving the efficiency and effectiveness of their performance monitoring.

Beyond the practices of data monitoring, a continued theme that arose throughout the thesis impacted the human element of data use and feedback. Results noted the importance of ensuring effective relationships between performance and coaching staff. This appears to be an underpinning factor in the effective implementation of performance data to practice. Research should explore manners of developing and assessing the strength of these existing connections.

A noteworthy finding observed within **Chapter 4** highlighted the lack of physical performance data use on matchday. Observational analysis emphasised that matchday had the lowest contact between performance data and stakeholders (in addition to the MD+1 recovery session). A potential limitation of the interview structure was that it did not investigate this idea further, however, evidence does support the notion that physical performance data use does produce the same level of intrigue and discussion on matchdays (Drust, 2019; Nosek, et al., 2021). Whilst it is understood that management and coaching staff have priority on match day for team selection and strategy, it seems rationale to explore the insights that performance data could support. Given that fatigue may be a limiting factor to match performance, and can result in injury, this is one potential avenue for exploration (Mohr, et al., 2005; Nedlec, et al., 2012; Hader, et al., 2019). The only reference to use of data on matchday by a member of coaching staff involved the use of loading data to get an insight into how players may report to training, by assessing their match demand.

Research has suggested that coaching staff believe sport science data is ‘not important’ when it comes to team selection and the outcomes of matches (Nosek, et al., 2021). Whilst research has shown that the support provided by physical performance staff can influence a club’s success, it is likely in this instance that coaches were referring the impact data can have upon the match day, as opposed to the preparation leading into a fixture and the long-term development of the squad. As such, it is unsurprising that observational analysis highlighted that game day contained the lowest contact points between physical performance staff and stakeholders. This finding agrees with a personal perspective article, suggesting that there is less involvement of the performance practitioner on a match day, from a data collection and decision-making perspective (Drust, 2019). This also agrees with the findings of **Chapter 3.** Despite the risks associated with overloading during congested fixture periods, physical performance data does not appear to be used in the match day planning process (Dupont, et al., 2010; Dellal, et al., 2015; Silva, et al., 2018). The impact physical performance data can have upon matchdays therefore would be a worthwhile investigative area for the continued advancement of physical performance support to soccer.

The scope of this research project extended to implementing an intervention to improve a small facet of the physical performance monitoring process, aiming to benefit physical capacity, a cornerstone of the player development process. Whilst **Chapter 6** successfully implemented a change to the practices within an elite youth soccer club, an appropriate future avenue of research would be to determine the changes such an intervention has upon the physical capacity of the players. Whilst the research in this project **(Chapter 5)** would suggest that this would likely result in improvements to physical capacity, a follow-up study could confirm such a change. Additionally, this project ended with a focus on physical fitness, where further research could develop a better understanding, and the identification of insightful metrics associated to other areas of the physical performance spectrum.

As discussed, a major theme of this thesis has examined the communication and feedback of information to coaching staff. In **Chapter 6**, the level of this feedback was basic, with a focus on presenting key metrics only. This intervention demonstrated the impact of simple feedback upon the planning and physical outputs of training sessions. However, future feedback should begin to incorporate a more reflective view of the measurement landscape, inclusive of data 'noise' (measurement error) (Atkinson & Nevill, 1998; Swinton, et al., 2023). It does appear that this is not the norm within professional soccer, with many practitioners not making the collection of this data standard practice (Asimakidis, et al., 2024). By educating both practitioners and stakeholders on the impact of these measurement error concepts, it is hoped the understanding and interpretation of data sourced findings can become more precise and impactful.

Finally, it would be beneficial to determine the impact of both intervention methods utilised in **Chapter 6**. Whilst both the report and discussion element were viewed as equally important, the understanding of the processes as to how these elements influenced change is important. This potential research could support practitioners by examining how each of these intervention methods can impact and influence the coaching decision making. Furthermore, it would be expected that over time, the impact of education may reduce, as coaches generate a greater understanding and potentially increased habitual use of the data. As such, research may illuminate an effective timescale for the implementation of such feedback and discussion processes.

8.1 Appendices

APPENDIX 1 – Survey (Digital Print Out Copy)

Section A: Participant Consent

Participant consent to research question, data collection in addition to participant meeting requirements and finally understanding of process to withdraw consent.

A1. **By selecting 'yes' below, you have read and accepted the outlined terms for participation, are older than 18 years of age, understand you are completing the survey voluntarily and work full-time within a professional European soccer club as a 'sport scientist' or similar role. You also understand that you are free to withdraw any submission you make, up to 7 days post completion of the survey**

This is a question help text.

Yes ☐

No ☐

Section B: Participant Information

The following section will collect general information relating to your position and experience as a performance practioner within professional soccer

B1. **What is the title of your current role within your club?**

☐

B2. **What level of soccer does the team you work with operate at?**

Professional Senior (Premier League, EFL, SPFL, Bundesliga etc) ☐

EPPP Category 1 (Premier League Elite Player Performance Plan) ☐

EPPP Category 2 ☐

EPPP Category 3 ☐

CAS Elite (Club Academy Scotland) ☐

CAS Development ☐

Other ☐

Other

☐

B3. **How many years have you worked within elite soccer (i.e., professional youth or senior professional level)?**

Please enter a numerical value only

☐

B4. **How many practitioners currently work full time (full time studentship is also accepted) within your immediate sport science/performance department (excluding medical/analysis/coaching). Please also detail the number of people who fill the below roles within the department you operate within. If the exact title is not listed, please select the closest description or 'other'.**

Total number of performance practitioners	
Head of Sport Science/Performance/Conditioning/(& Medicine)	
Head of Strength and Conditioning	
Lead Sport Scientist	
Lead Strength and Conditioning Coach	
Assistant Sport Scientist	
Assistant Strength and Conditioning Coach	
Data Analyst (Dedicated Data Role)	
Rehabilitation Coach	
Student	
Other	

Section C: Current Monitoring Practices

The following section will collect a general overview of the monitoring scope at your club

C1. **Please select if and how often data is collected on the following physical performance areas?**

	Yes	No
External Load Monitoring (e.g., Total Distance, acceleration count)	☐	☐
Internal Load Monitoring (e.g., Maximum Heart Rate, Time >90% Max Heart Rate)	☐	☐
Subjective Rating of Perceived Exertion (RPE or Similar)	☐	☐
Subjective Wellness Scoring (e.g., Lower Body Soreness)	☐	☐
Neuromuscular Fatigue Assessment (e.g., Jump Scores, Rate of Force Development)	☐	☐
Biochemical Markers (e.g., blood analysis, urine osmolality)	☐	☐
Internal Response Assessment (e.g., Heart Rate Variability)	☐	☐

	Yes	No
Performance Capacity Testing (e.g., 40m Sprint, 30:15 IFT Final Stage)	☐	☐
Body Composition Analysis (e.g., Height, Tricep Skinfold)	☐	☐
Gym Based Assessment (e.g., Load Lifted, Velocity of Lifts)	☐	☐

C2. Please select if and how often data is collected on the following physical performance areas?

	Daily	Weekly	Monthly	Quarterly	6-12 months	On Request
External Load Monitoring (e.g., Total Distance, acceleration count)	☐	☐	☐	☐	☐	☐
Internal Load Monitoring (e.g., Maximum Heart Rate, Time >90% Max Heart Rate)	☐	☐	☐	☐	☐	☐
Subjective Rating of Perceived Exertion (RPE or Similar)	☐	☐	☐	☐	☐	☐
Subjective Wellness Scoring (e.g., Lower Body Soreness)	☐	☐	☐	☐	☐	☐
Neuromuscular Fatigue Assessment (e.g., Jump Scores, Rate of Force Development)	☐	☐	☐	☐	☐	☐
Biochemical Markers (e.g., blood analysis, urine osmolality)	☐	☐	☐	☐	☐	☐
Internal Response Assessment (e.g., Heart Rate Variability)	☐	☐	☐	☐	☐	☐
Performance Capacity Testing (e.g., 40m Sprint, 30:15 IFT Final Stage)	☐	☐	☐	☐	☐	☐
Body Composition Analysis (e.g., Height, Tricep Skinfold)	☐	☐	☐	☐	☐	☐
Gym Based Assessment (e.g., Load Lifted, Velocity of Lifts)	☐	☐	☐	☐	☐	☐

C3. Please select the current technology/methods used to collect physical performance data within your club

	Yes	Uncertain	No
Micro-electrical Devices (Inc those with integrated GPS)	☐	☐	☐
Internal Monitoring Device (e.g., HR Monitor)	☐	☐	☐
Rating of Perceived Exertion Scale (RPE, dRPE or similar)	☐	☐	☐
Biochemical Markers (e.g., Urine, Blood)	☐	☐	☐
Speed Monitoring (Radar Gun, Timing Gates, etc)	☐	☐	☐
Force Platform	☐	☐	☐
Jump Mat (e.g., Optojump, JustJump, etc)	☐	☐	☐

	Yes	Uncertain	No
Strength Testing Equipment (e.g., Nordboard, Groinbar, etc)	☐	☐	☐
Velocity Based Training Device (e.g., Flex, GymAware, 1080motion, etc)	☐	☐	☐
Aerobic Fitness Protocol (e.g., 30:15, Yo-Yo Intermittent Recovery Test, etc)	☐	☐	☐
Body Composition Analysis (e.g., Duel Energy X-Ray Absorptiometry, Skinfolds, etc)	☐	☐	☐

C4. As an estimate, how many individual metrics (e.g., total distance (m), Maximal Jump Height, Lower Body Soreness) do you collect per player on the following areas per monitoring period (i.e., if collected daily, how many metrics daily or if collected quarterly, how many metrics within each individual collection period). If not collected, leave blank

	External Load Monitoring (e.g., Total Distance, acceleration count)	Internal Load Monitoring (e.g., Maximum Heart Rate, Time >90% Max Heart Rate)	Subjective Rating of Perceived Exertion (RPE or Similar)	Subjective Wellness Scoring (e.g., Lower Body Soreness)	Neuromuscular Fatigue Assessment (e.g., Jump Scores, Rate of Force Development)	Biochemical Markers (e.g., blood analysis, urine osmolality)	Internal Response Assessment (e.g., Heart Rate Variability)	Performance Capacity Testing (e.g., 40m Sprint, 30:15 IFT Final Stage)	Body Composition Analysis (e.g., Height, Tricep Skinfold)	Gym Based Assessment (e.g., Load Lifted, Velocity of Lifts)
0-5	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
5-10	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
10-20	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
20-50	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
50-100	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
100+	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

C5. Do you collect data on any other area of physical performance? If so, please list the area, how often it is collected, the method of monitoring and an estimate of the number of metrics collected per player.

Section D: Data Processing

The following section will examine the methods used to process and analyse collected physical performance data

D1. What methods are currently used within your club to process data?

- Standard Computer Software (e.g., Numbers, Excel) ☐
- Data Visualisation/Analysis (e.g., Power BI, SPSS, Tableau) ☐
- In Built Analysis (e.g., Catapult, Statsports, Playermaker) ☐
- Athlete Management Systems (e.g., Kitman Labs, Edge 10, Apollo. Sport Office) ☐

Artificial Intelligence (e.g., Zone 7) ☐

No Data Analysis ☐

Other ☐

Other

D2. As an estimate, how much of the data collected in the following categories is actually processed/analysed? If the area is not examined, leave the relevant row blank.

1 - Very Little to None is Used; 2 - Most Data is Unused, 3 - Some Data is Used; 4 - Most Data is Used; 5 - Almost all to all data is used

	1	2	3	4	5
External Load Monitoring (e.g., Total Distance, acceleration count)	☐	☐	☐	☐	☐
Internal Load Monitoring (e.g., Maximum Heart Rate, Time >90% Max Heart Rate)	☐	☐	☐	☐	☐
Subjective Rating of Perceived Exertion (RPE or Similar)	☐	☐	☐	☐	☐
Subjective Wellness Scoring (e.g., Lower Body Soreness)	☐	☐	☐	☐	☐
Neuromuscular Fatigue Assessment (e.g., Jump Scores, Rate of Force Development)	☐	☐	☐	☐	☐
Biochemical Markers (e.g., blood analysis, urine osmolality)	☐	☐	☐	☐	☐
Internal Response Assessment (e.g., Heart Rate Variability)	☐	☐	☐	☐	☐
Performance Capacity Testing (e.g., 40m Sprint, 30:15 IFT Final Stage)	☐	☐	☐	☐	☐
Body Composition Analysis (e.g., Height, Tricep Skinfold)	☐	☐	☐	☐	☐
Gym Based Assessment (e.g., Load Lifted, Velocity of Lifts)	☐	☐	☐	☐	☐

D3. Does internal research (that involving members of the clubs own staff conducting research independently or in association with an educational institute) within your club influence what data is collected or inform upon the methods of data analysis and processing, such as the statsictical methods used? If yes, please specify those involved (i.e., staff only or in collaboration with a university).

D4. **Please briefly outline any common processing and/or statistical analysis methods used to analyse collected physical performance data within your club (e.g., comparison to average, smallest worthwhile change, magnitide based inference, A:C Ratio)**

D5. **Please detail, with reference to the above questions, any other areas of physical performance data collected.**

Section E: Data Feedback

This following section will examine how data is analysed within your club and how this processed data is fedback.

E1. **Who within your club receives processed data, and how often do they receive this data? This can relate to any of the aforementioned data streams.**

	Yes	No	Unsure
Sport Science Staff	☐	☐	☐
Coaching Staff	☐	☐	☐
Players	☐	☐	☐
Medical Staff	☐	☐	☐
Management Staff (e.g., Head of Academy, Director of Football, Board Members etc)	☐	☐	☐
Analysis Staff	☐	☐	☐
Scouting Staff	☐	☐	☐
Others	☐	☐	☐

E2. **Who within your club receives processed data, and how often do they receive this data? This can relate to any of the aforementioned data streams.**

	Daily	Weekly	Monthly	3-12 Monthly	On Request	Not Received
Sport Science Staff	☐	☐	☐	☐	☐	☐
Coaching Staff	☐	☐	☐	☐	☐	☐
Players	☐	☐	☐	☐	☐	☐
Medical Staff	☐	☐	☐	☐	☐	☐
Management Staff (e.g., Head of Academy, Director of Football, Board Members etc)	☐	☐	☐	☐	☐	☐
Analysis Staff	☐	☐	☐	☐	☐	☐
Scouting Staff	☐	☐	☐	☐	☐	☐
Others	☐	☐	☐	☐	☐	☐

E3. **For those key stakeholders who are provided processed data, what information do they receive and in what format? (i.e., individual player training report, combination of graphs and tables via printout and verbal feedback) Where multiple pieces of information are provided, please provide a general overview. If no data is fedback, leave blank.**

Sport Science Staff	
Coaching Staff	
Players	
Medical Staff	
Management Staff	
Analysis Staff	
Scouting Staff	
Others	

E4. **Please select the most appropriate response to the following questions regarding the utililisation of the processed data.**

1 - Never; 2 - Rarely; 3 - Sometimes; 4 - Often; 5 - Always

	1	2	3	4	5
Is processed physical performance data reported to key stakeholders in a timely manner to allow for appropriate decision making?	☐	☐	☐	☐	☐
Is physical performance data used to compare between players?	☐	☐	☐	☐	☐
Is physical performance data used to determine training content/physical demand?	☐	☐	☐	☐	☐
How often does physical performance data determine whether a player trains or not?	☐	☐	☐	☐	☐
How often does physical performance data determine whether a player plays a match or not?	☐	☐	☐	☐	☐
Is physical performance data used to determine physical development training of players?	☐	☐	☐	☐	☐
Is physical performance data used in talent selection processes?	☐	☐	☐	☐	☐
How often do meetings/conversations take place between sport science and coaching staff regarding physical performance data?	☐	☐	☐	☐	☐

E5. **Please list between 5 and 15 physical performance metrics that are used most often in the decision making process within your club (e.g., total distance (m)).**

Section F: Practitioner Opinion

This final section will ask of your opinion upon certain areas of data usage in football.

F1. **Please list, in order of importance to you, the primary purposes of monitoring physical performance data within football (e.g., injury prevention, physical development)**

#1 Importance

#2 Importance

#3 Importance

#4 Importance

#5 Importance

F2.	**Do you feel that your current physical performance data collection and processing practices allow you to achieve your above listed primary purposes of physical performance monitoring? What requires improvement to allow you to achieve this if not the case?**	
F3.	**How would you rate the current return on investment for current physical performance data monitoring practices (e.g., technology, processes, specialist staff) within your current club?**	
F4.	**Has there been a change in the volume of physical performance data collected within your time working in professional football? Please detail in which direction it has changed, if you believe it has.**	
F5.	**How do you feel physical performance data monitoring and feedback is currently received (i.e., wanted/understood) and utilised (i.e., informs decision making) within football generally? Where do you see key changes being?**	

F6. **Do you have any futher comments you would like to make about physical performance data processes in football?**

Thank you for taking the time to complete this survey.

Please contact the research team if you have any questions relating to this research.

APPENDIX 2 – Participant Information Form

Dear *Practitioner*,

I am contacting you in regard to my PhD research project, "***Evaluating the Effectiveness of Physical Performance Data in the Player Development Processes in Professional Soccer",*** in collaboration with University of Birmingham and Rangers Football Club. This study has been approved by the University of Birmingham's ethics committee (ERN_2022-0259).

The research project aims to explore the utilisation of physical performance data in elite level soccer in supporting the development and performance of players. Physical performance data will encompass data pertaining to, but not limited to, 'internal and external load monitoring', 'physical testing (e.g., testing batteries)', and 'physical readiness/wellbeing assessments' e.g., 'fatigue monitoring'.

The first component of this research is an online survey aimed at practitioners involved in the physical development of professional soccer players. To complete this survey, it is expected that you are currently working full-time (full time studentship is also accepted) within a professional soccer club, engaged in daily practice with professional football players as part of a 'performance department' with two or more full-time members.

Contribution to the study is entirely voluntary and all participants will have the right to withdraw their online response for a period of 1 week following submission. If you would like to participate with the survey, please follow the link attached to this correspondence. The survey will take no longer than 10 minutes to complete. Should you wish to complete this short survey, please read the attached document outlining withdrawal and data protection procedures.

Your involvement in this study would be greatly appreciated, in allowing us to better understand and progress the physical performance data landscape of professional soccer and assist in bettering the player development process. The research group will make results of the research available to yourself following completion of the research project.

Kind regards,

Calum MacMaster – PhD Research Student

Professor Barry Drust – Primary Supervisor

The questionnaire can be accessed using the following link:

https://lime.bham.ac.uk/index.php?r=survey/index&sid=787157&lang=en

Dear *Practitioner*,

Please take time to read the below, prior to beginning the survey.

Thank you for agreeing to taking part in the first research area of a complete research project investigating the utilisation of physical performance data in professional soccer. This survey will aim to establish the physical performance data landscape across European professional soccer. The survey should take no longer than 10 minutes to complete and is composed of multiple-choice responses and short sentence/list answers.

By completing this survey, you will provide insightful information that will form the basis of research into current practices surrounding how physical performance data is used in professional soccer and its effectiveness in impacting decision making and performance. Results from the study will be made available to yourself at the completion of the full research project, however, results pertinent to this section of the project can be made available sooner, on request to the research team listed below.

In accordance with the 2018 General Data Protection Regulation (GDPR), all participants and their employee will remain anonymous. Only personal data relating to the club's league status in addition to practitioner's experience levels will be collected. Responses will only be accessible to the research team and all information will be stored securely. Responses will be held for a necessary period of time (maximum 10 years) in accordance with the University of Birmingham's data retention and disposal protocols.

Data will only be collected upon completion and submission of the survey via the final page. Participants are free to withdraw from the survey at any point during or after submission of survey. If requesting to withdraw from the survey, please contact the research team to complete this process. The final date to withdraw your survey submission will be set at **7 days** following completion of the survey, as analysis on the results may begin after this period. No reason for withdrawal of your survey submission is required. Please ensure you have available the time and date of survey submission to allow for retrieval and deletion of the appropriate survey response.

Research Team

Calum MacMaster – or

PhD Candidate

Professor Barry Drust –

Primary Supervisor

Consent

By selecting ‘yes’ on the first question of the questionnaire, you confirm that you have read and accepted the above terms, are older than 18 years of age, understand you are completing the survey voluntarily and work full-time within a professional football club. Additionally, you understand that you are free to withdraw any submission you make up until 7 days post completion.

Thank you.

APPENDIX 3 – Observational collection forms

Date: **Match Day (+/-):** **Squad:**		**Physical Performance Data Observations**				
Physical Performance Data Involved (e.g., player wellbeing)	**Timing of Event (e.g., pre-training)**	**Action Involved (e.g., collection, analysis, feedback, discussion etc)**	**Method/Technology/Software Involved (excel, catapult)**	**Stakeholders Involved (e.g., sport scientist, coaching staff, players)**	**Number of Metrics Involved**	**Outcome of Action**
Player Wellbeing	*Pre-Training (Player Arrival)*	*Data Collected, Viewed and Fed Back*	*Football Squad*	*Players, Sport Scientists, Coaching and Medical Staff*	*5 Metrics (LB Soreness, Sleep, Readiness & Fatigue)*	*1 Player Alert Raised Regarding LB Soreness, Conversation Taken Place – Still Trained*

Age Group: **Week:**	**Physical Performance Data Frequency - Weekly**			
Physical Performance Area	**Frequency + Match Day Frequency**	**Data Involved (Common Metrics)**	**Timing (e.g., Pre-Training)**	**Stakeholders Involved**
Player Training/Match Involvement Altered Due to Loading Data				
Player Training/Match Involvement Altered Due to Wellbeing Data				
Discussion Around Player Loading				
Data Feedback to Coaching Staff				
Data Feedback to Players				
Interaction from Stakeholders Based off Feedback				
Live Monitoring Used to Alter Training/Game During Session				
Error in Collection/Item of Data Not Collected (e.g., player not reporting, unit error)				
Enquiry Raised About Physical Performance Data by Stakeholder				

Date: **Match Day (+/-):** **Squad:**	**Physical Performance Data Frequency - Daily**				
Physical Performance Area	**Collected (Y/N)**	**Number of Metrics (Per Player)/% Of Response (Per Team)**	**Data Analysis Conducted (Y/N)**	**Data Fed Back (Y/N)**	**Action Taken (Y/N)**
Wellbeing Data					
Player Physical Loading (Pitch)					
Player Physical Loading (Pitch) - Live					
Player Physical Loading (Gym)					
Player Physical Performance Testing					
Player Fatigue Screening					
Review of Physical Loading					
Review of Other Physical Data					

APPENDIX 4 – Staff interview questions

Interview Section	Question	Purpose/Desired Outcome	Probing Question/Sub-Question
This section will be an introduction to the survey setup. It will just allow you to highlight your involvement in football			
1 – Participant Background/Establishing Questions	1. How long have you been involved in professional football?	Allow participant to open and begin to converse. Ease into interview setup.	What are the biggest changes you have noticed in football since you first got involved at a professional level? Do you think the game has improved since that change?
	2. How would you describe your current role within the club?		Daily, who do you interact with? Who are your closest working relations with?
This section will look at your views on physical performance (i.e., speed, power, strength, fitness, robustness)			
2 – Introduction to Physical Performance in Football	1. What influence do you feel a player's physical abilities have upon their footballing performance levels.	Establish interviewees views on importance of physical performance on soccer	What are the most important physical qualities a player should possess for success in soccer Should more or less time be spent training? Does the gym have a good or bad reputation amongst players?
	2. In your time involved in football, have you noted any differences in the physical demands of the sport?	Understand what new trends in physical demands are. What does the modern player need?	A research paper titled Elite football of 2030 will not be the same as that of 2020 was recently published. They stated that there was 2.5 times increase in training and matches from 2001 to 2014. To what extent do you agree with the statement that football won't be the same in the years to come, with particular focus on the physical aspect?

	3. Please explain in your own words, what "player development" involves. What outcomes do you feel are required for "player development" to be successful.	Allow participant to understand what a holistic development approach is	Our player development looks at keeping players robust and fit, physically developing towards elite levels and able to successfully compete.
This section will explore the physical performance data collected at the club. This will cover load monitoring, player readiness to train and physical performance testing data.			
3 – Introduction of Data	1. In your role within the club, how much data do you interact with generally?	Establish data overview	What comparison would be made to subjective data?
	1. In the player development process, what importance does objective data, that being fact, have? And how does it compare to subjective data or opinion.	Importance of objective data	Would you scout or decide on a player based upon purely objective data?
	2. What steps are required for data to become effective in its purpose?		What needs to be done to turn data and facts into decision and supporting information.
4 – Introduction to Physical Performance Data in Football	1. The sport science department within the club collects a wide range of data relating to the physical performance of the soccer players. Are you aware of any of the collected data?		We currently collect around 60 metrics per player per day. Do you think this is excessive? 51+5+2+2
	2. Why do you think the sport science department collect this data? Do you think this is a worthwhile task?		Prompt on some of the data

	3. During your day, you may interact with data. What and when do you interact with data?	Create data flow	Pre-training, during training, post-training, reviews, and on-request.
	4. What do you do with the data you receive and does it have any importance or support decision making in the player development process.	Use and effectiveness of data	How well do you understand the data you receive? What could help you understand it better? Prompt on specific data to get an idea of data flow
	5. What is the most important physical performance data you receive?		Does the physical performance that is collected and fed back to you support you in your role?
	6. Where do you feel improvements in the data flow of physical performance data within the club could be?	How can we improve? – Study 4	
	AOCB		

APPENDIX 5 - Staff interview questions and Likert scale response questions

Interview Section	Question	Purpose/Desired Outcome	Probing Question/Sub-Question
Intervention			
	1 – Did the modified feedback and focused discussion change your session planning process? If so, what changed?		Were you more aware of these metrics when planning sessions?
	2 – Did you notice any changes to the session		If changes were noticed, did you notice a change in player engagement?
Post-Intervention	3 – What was your opinion of the modified feedback provided?		Was the feedback similar or different to your perception of the sessions?
	4 – Did you feel the modified feedback increased your understanding of the physical demands required to increase physical fitness		
	5 – What element of the feedback did you find more impactful? The written report or the verbal discussion?		

Likert Scale Questions

To what extent do you agree or disagree with the following statements. (Scale available to view)

1 – Strong Disagree

2 – Disagree

3 – Undecided

4 – Agree

5 – Strongly Agree

1 - The focused feedback and discussion surrounding total distance and heart rate exertion increased focus on these metrics during the session planning phase.

2- The focused feedback and discussion surrounding total distance and heart rate exertion increased focus and resulted in a change to session planning

3- The adapted feedback and discussion increased focus on the key metrics, and how players responded to the session, in post-session discussions.

4 – You noticed a difference to the sessions, in terms of an increase to physical demand/intensity.

5 – You found the verbal discussion beneficial to increasing your awareness and understanding of the physical demands required to increase performance

6 – You found the physical report (containing the two metrics) beneficial to increasing your awareness and understanding of the physical demands required to increase performance

APPENDIX 6 - Player interview questions and Likert scale response questions

Interview Section	Question	Purpose/Desired Outcome	Probing Question/Sub-Question
Intervention			
	1 – Did you notice any changes to the session with regards to physical demand		If changes were noticed, did you notice a change in player engagement?
Post-Intervention	2 – Did you notice any changes to the coaches approach to training, with regards to session setup, planning, or delivery?		

<u>Likert Scale Questions</u>

To what extent do you agree or disagree with the following statements. (Scale available to view)

1 – Strong Disagree

2 – Disagree

3 – Undecided

4 – Agree

5 – Strongly Agree

1 – You noticed a difference to the sessions, in terms of physical demand/intensity.

2 – Training sessions were physically more challenging

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