EXAMINING THE RELATIVE IMPORTANCE & EFFECTIVENESS OF STRATEGIES FOR PHYSICAL DEVELOPMENT IN ELITE YOUTH SOCCER PLAYERS

By

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A thesis submitted to the University of Birmingham for the degree of
DOCTOR OF PHILOSOPHY

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February 2021

ABSTRACT

The demands of soccer are multifactorial, from a physical perspective, the intensity of soccer match-play has significantly increased in recent years. The training methods that are employed by practitioners must constantly evolve to ensure players are in a position to cope with these demands across the season. Furthermore, to perform at the very highest level, an elite soccer player must excel in physical capabilities while concurrently demonstrating excellent technical and tactical skills. However, there is little information available regarding the physical development strategies that elite soccer clubs currently employ in order for youth soccer players to develop with the required attributes to be able to cope with the demands of senior soccer.

Study 1

The first study aimed to understand the coach′s perspective on the importance of physical development to the success of elite youth soccer players. A qualitative interview was conducted at an English premier league (category 1) academy. Fitness coaches, technical coaches, and an academy director were asked questions in an attempt to understand the training approaches in place and the rationale behind them, specifically concerning the physical aspect of the program. An understanding of the coaches′ perspectives on the relative importance of physical development within the overall development program could then be observed. The present study′s findings showed that elite coaches deemed the physical development of players as a key aspect in a holistic programme of player development. More specifically the following conclusions were made; the academy program is designed to prepare players for their first team squad, the coaches were keen to stress that developing good people was also a pertinent feature of the academy syllabus and that winning matches was not important in academy soccer (although it may be used a tool to successfully reinforce ideas to players). In addition, coaches were keen to stress that physical performance improvements would allow players to spend more time training due to less injury, therefore increased opportunities to learn and develop as a player.

As aforementioned an important point that was raised was that match involvement was a vital part of a player's development, however, winning matches within this academy setting was not, as coaches suggested that the match was merely an extension of the training schedule within this cohort of players. This study's findings allowed us to provide new insights into the different approaches used for physical development and potential barriers and future areas of improvement too within elite youth soccer. Given the expertise of the coaches interviewed, soccer practitioners could consider the findings useful for a better understanding of the methods of physical development integration in a holistic program. Furthermore, with the findings of both chapter 3 and 4 in question, the specific structure of chapter 5 was developed to attempt to understand if what the coaches perceived was important (i.e match involvement) was then reflected when it was analysed in practice.

Study 2

The aims of the second study (chapter 4) were as follows; (i) to understand which physical tests are sensitive to identify changes across respective periods (ii) to understand the respective relationship of these tests with measures of internal and external training load. To investigate these aims, a systematic review was conducted. Five electronic databases were searched (PubMed Medline, SPORTDiscus, Web of Science, CINAHL, and Scopus), with three additional studies identified from Science and Medicine in Football Journal. A total of 5683 studies were identified after removing duplicates, with only 30 meeting the search criteria. The findings reported within this review, show that a maximal aerobic speed (MAS) test, YoYo Intermittent test derivatives and laboratory-based incremental running tests seem to be sensitive enough to detect aerobic and anaerobic capacity changes across respective training periods. The use of countermovement jumps (CMJ) to detect lower body power changes may be useful, however, ensuring the correct variables such as jump height via impulse and flight time:contraction time are measured is imperative. Also, maximal sprint testing (>30 m) may be used for speed-based changes. Findings from this study were then applied to study 3 (chapter 5) of the thesis by providing invaluable information to design and implement the longitudinal tracking of training load and fitness change study. Following this review, it was clear that there is limited evidence in youth soccer that accurately monitors TL in relation to

physical development. Therefore, further research is required to understand the best methods to track and monitor physical development allowing for a consensus of best practices to use within professional youth soccer to be made (chapter 5).

Study 3

The study's primary aim was to quantify the accumulative training and match load across an annual season in elite academy soccer. In doing so, its effectiveness in relation to internal physical performance development across this time frame could be observed. Furthermore, this research aimed to understand how training influences athlete performance. Finally, an analysis of the key parameters which may provide correlations to allow for an understanding between TL and changes in fitness with the submaximal YoYo IE2 fitness test across an elite youth soccer season. In addition, an understanding of how much of the physical stimulus comes from the training prescription and how much comes from matches in periods two, four, and six weeks before the physical testing period. The key finding of this study was that when the starting status was accounted for concerning the examination of aerobic fitness; Starters had a consistently lower heart rate (HR) in the submaximal YoYo IE2 across the season (apart from Evaluation point 1; E1). Using Pearson's correlation, it was evident that there were moderate correlations with number of matches played, total duration of training, total distance (TD) performed and total high-speed running (HSD) between tests, with the strength of the correlation increasing the further from the test. At six weeks the correlations were strongest; Number of Matches Played (-0.33), Total Duration of Training (-0.45), TD Performed (-0.51), and HSD (-0.42), Sprint SPR (-0.32) and total a/ds (-0.4) were found. This suggests that the more training and matches a player completes the lower the players maximum HR in the test. The findings of our study also demonstrate that there are significant differences in physical fitness for players who are consistently involved in match play in comparison with those who are not.

Study 4

In order to provide information as to how to close the gap between players who play regularly in matches with those who do not in terms of physical stimuli, it was important to provide recommendations to do so. Therefore, the aim of study 4 was to provide a commentary which summarises the scientific rationale, current literature and practical recommendations to maintain and develop physical fitness in professional soccer. This was divided into six sections: 1) Evidence-based training load methodologies for maintaining and developing squad fitness; 2) How to keep players 'ready to play' who are not involved regularly within competitive match play; 3) How should interventions be implemented to close the gap between players who receive varied accumulative physical loads?; 4) What other methods could fitness coaches implement to allow for development/maintenance of fitness of players who are regular non-starters?; 5) Recommendations for effective implementation of top ups and post-match conditioning to prepare all players from a physical standpoint in applied soccer settings; 6) Limitations and future directions. The contemporary literature provides preliminary methodological guidelines for coaches and practitioners to use. The recommendations include; Individual periodization of training should be based on starting status (e.g. starters or non-starters) and match position demands in order to optimize recovery, match-day performance and overall physical development. Practitioners should understand how manipulating SSG variables such as pitch size and duration affect mechanical, metabolic and acute physiological responses to allow for appropriate top up protocols to be implemented. In relation to designing top up sessions, medium and large SSG can be used to ensure HSR and SPR exposure demands are met, with smaller SSG allowing for mechanical based adaptations. Isolated running drills may also be used within conditioning sessions to provide appropriate conditioning stimuli.

Summary

In summary, this research program provides novel information about the training loads and changes in physical fitness in elite youth soccer players. In addition, this work systematically examined the training load across a competitive youth soccer season to understand how significant the involvement in match play is for physical performance markers. Furthermore, it was the first study to conduct this type of qualitative interview with elite youth soccer coaches to further understand the relative importance of physical development in elite youth

soccer. It is hoped that the findings from this research project can help applied staff understand the most appropriate practices surrounding match play in long term development programs for elite youth players.

Acknowledgements

Completing this PhD process whilst working full time in elite soccer was a challenging but extremely rewarding journey. I strongly believe the skills I have gained and the people I have met and worked with whilst undertaking these studies have shaped not only my professional career but my personal values. For certain, I could not have done this alone without support and I would like to give a special thankyou to the following people:

Professor Barry Drust. Firstly, I would like to thank my Director of studies, I could not have wished for a better person to guide me through this process. I believe that you have not only developed my academic capabilities but also been a huge part in my personal development. The enthusiasm that you showed towards my research project was evident from our first conversation, so I hope that you are happy with how it has all 'come together'. As this thesis was completed in conjunction with working full time at Liverpool Football club, and also amidst a global pandemic, there has been lots of challenges along the way and I thank you for your continued support and guidance at every stage of the journey. Finally, without you facilitating such a difficult process I would not be in the position or job role that I am today. I hope I have justified the faith you have shown me on numerous occasions and that we can continue to work together in the future and collaborate in applied work to continually push practices within the field.

Dr James Malone, Dr Tom Brownlee & Dr Allistair McRobert. As my PhD was very much a 'team' effort, I would like to give a special thanks to James, Tom and Allistair. As with Barry, thank you for your continued help and support throughout this process, I have thoroughly enjoyed working with you all and this project is just as much yours as it is mine!

Dr Jack Ade. I would like to thank you for the opportunity to conduct this research and develop as a practitioner under your guidance at Liverpool FC. I appreciate all the help you

have given to me over the past three years which has helped me develop into the practitioner I am today.

Jordan Milsom. Thanks for the support and guidance throughout the early stages of my PhD at Liverpool and for taking me under your 'wing' when we worked together. The faith you showed in me during the first year at Liverpool gave me great confidence in my ability to work within this environment.

John Hill. Working closely with you was a pleasure and I cannot thank you enough for your continued support and the interest you took in my personal development. It is a pleasure to call you a great friend and someone I can continually lean on for guidance both personally and professionally.

Mum. I know you hated and still hate every minute of me living away, but I am extremely grateful for your love and support throughout. Thanks for all the faith you have shown in me and now this is finished hopefully we can spend some quality time together when I am back home rather than me constantly having my head in the computer!!

Dad. Thanks for always pushing me and for providing support over the years to allow me to pursue this career so I didn't have to join you on the building site ;). Look forward to having some good father-son time in the future and hopefully reaping the rewards of all this hard work.

I would also like to thank Dr. Liam Harper for his advice regarding the systematic review process. In addition, a special thanks to Liverpool Football Club for financially supporting my studies.

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LIST OF ABBREVIATIONS

A/Ds	**Accelerations & decelerations**
CB	**Centre Back**
CM	**Centre Midfield**
CMJ	**Countermovement Jump**
COD	**Change of Direction**
CV	**Coefficient of variation**
E (n)	**Evaluation (n=time point)**
EPPP	**Elite Player Performance Plan**
FA	**Football Association**
GPS	**Global Positioning systems**
HPG	**high minutes of available match playing time >250**
HR	**Heart Rate (beats.min-1)**
HRmax	**Percentage of Maximum Heart Rate**
HSD	**High Speed distance**
IMTP	**Isometric mid-thigh pull**
iTRIMP	**individualised training impulse**
LPG	**low minutes of available match playing time (LPG)**
LTAD	**Long Term athletic development**
M	**Metres**
MAS	**Maximal Aerobic Speed**
MD	**Matchday**

RPE	**Rating of perceived exertion**
RSA	**Repeated Sprint ability**
SEM	**Standard error of measurement**
SPR	**Sprint distance**
SSG	**Small sided games**
TD	**Total Distance**
TT	**Technical/Tactical**
$\dot{V}O_{2max}$	**Maximal oxygen uptake (L.min-1)**
WU	**Warm Up**
YYIE2	**Yo-Yo intermittent endurance test level 2**

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CHAPTER ONE

GENERAL INTRODUCTION

Background

Soccer is one of the most, if not the most, popular sports in the world. With the popularity of the sport exponentially growing, professional soccer and the financial rewards associated with elite soccer have never been bigger. As such, teams are always analysing and searching for ways to gain the edge on their rivals, to both outperform on and off the pitch. In doing so, one way is through the investment in their academy systems, allowing players to potentially gain a pathway to the first team, without having to outlay funds to buy players from other teams which is observed frequently in the current climate. To successfully achieve this, soccer clubs aim to persuade the best and most talented players to join their academy program. Once the players are part of their program, they can then use their coaches and support staff alike to implement programs to optimise performance levels of the player.

Soccer is a highly complex intermittent sport with activity patterns that contain both high and low-intensity efforts. These patterns lead to a high level of both anaerobic and aerobic energy turnover during a soccer match (Bangsbo, 1994). Therefore, it is imperative to recover between the anaerobic activity to produce high physical outputs for the successful outcome of elite soccer players technical actions such as passing and shooting (Mohr et al., 2003). Due to this physiological stress and with match play in soccer dependent on these other factors such as psychological, tactical and technical elements, a strong physical profile will allow for such technical actions to be more competently performed. As such, it is evident that there are

multiple components to performance and that all should be included in successful development programs. Although it is evident that players should be physically adept in order to perform the technical skills required to outperform their opponents, we do not currently understand the focus of key stakeholders' views on the relative importance of physical development in elite youth soccer. An understanding of the focus which coaches place on different aspects of physical development could help both researchers and practitioners working within youth soccer to more effectively design training programs to develop athletes and successfully transition into elite soccer.

Recent research has highlighted the professional soccer evolution in the English Premier League both from both a technical and physical perspective due to the increased physiological demands imposed on the players (Barnes et al., 2014; Bradley et al., 2016). To ensure youth players are prepared for the transition to first team soccer it seems important to evaluate the programs and training processes which players are exposed to. Currently there is little information which describes the effects of this varied training and match involvement on the long-term physical development of soccer players. As such, it is unknown whether the training a youth player is performing is optimal for the holistic and, more importantly the physical long-term development. With it being well understood that these training processes a player is exposed to are of paramount importance to prepare the player, both for long term development and short-term match readiness, a thorough understanding therefore seems vital. It should be noted that this process is multifaceted, in which all factors, including physical, can be developed in tandem (Morgans et al., 2014; Walker & Hawkins, 2017). To successfully evaluate these programs, it is imperative to have sensitive tests and approaches to monitor training load. In doing so these programs can be evaluated for their effectiveness in providing players with the stimulus required which is associated with improvements in their physiological function over time. Furthermore, there is a requirement to understand the important components of the activities which players complete that contribute to the stimulus. For instance, a potential tool to develop this physical capacity in soccer players could be through match involvement. Within youth soccer, teams will often be involved in one or two matches per week, and due to the youth soccer program primarily being focused on development, this perhaps limits the potential opportunity for training. In contrast when periods of fixture congestion are not observed, there is only one competitive soccer match

per week. There may be opportunity for structured training for both technical and tactical performance development. Overall, there is little understanding as to how the modulation of match play influences physical development measures regarding the long-term preparation of youth soccer players.

To analyse these training programs, as previously described, it is essential to have an appropriate measure of training load and also, accurate tests to detect change in physical fitness. Several methods exist to monitor training load, with the measures such as Heart rate (HR) and Global positioning systems (GPS). The training process has previously been broken into external and internal load (Impellizeri et al., 2005). The same author (Impellizeri et al, 2005) defined the external training load as "the training prescribed by the coaches", with the internal load referring to "the physiological response to the external training stimulus". The training response to this load, refers to the accumulation of individual training sessions, ranging from a single week to several months throughout an annual cycle (Bompa, 2009). Other authose have found made reference to the chronic response of soccer training during both the pre-season (Jeong et al., 2011) and in-season (Impellizeri et al., 2006; Jeong et al., 2011) phases, however these studies were in senior soccer.

Finally, to conclude, it is not currently known how this varied involvement in match play affects a player's physical development and the potential strategies that may be effective to close the gap between any difference that may occur in players' physical loading strategies. Therefore, this thesis aims to investigate the relative importance of physical development strategies, including the coach's perceptions of these and strategies to potentially increase the physical development of players exposed to less training stimuli.

Aims and Objectives

The purpose of this thesis was to evaluate the relative importance and effectiveness of strategies for physical development in elite youth soccer players.

The aims of the thesis are:

- Understand the perspective of key stakeholders in the development process (i.e. coaches) towards the importance of physical development to the success of elite youth soccer players

- Identify physical tests that have potential to be sensitive to identify changes in physical fitness and to understand the relationship of measures of internal and external training load with test outcome

- To evaluate the role of match-play in changes in the physical performance of elite youth soccer players across a competitive season

- To provide evidence-based training load methodologies for maintaining and developing squad fitness and in addition provide recommendations on how to keep players 'ready to play' who are not involved regularly within competitive match play.

CHAPTER TWO

LITERATURE REVIEW

Introduction

Soccer performance is influenced by physical, technical, tactical, and psychological factors (Bangsbo, 2015). Therefore, coaches who work within soccer have the unique challenge of preparing and developing soccer holistically. At present, there is little information on coaches′ perspectives as to the importance of physical development as part of the long-term program for soccer players. It is evident that physical training should be based upon both the players′ current physical status and the associated demands of their specific playing positions. As such, coaches and practitioners are required to not only understand why, but also how and when specific training measures should be prescribed (Turner et al., 2016). This literature review will identify the demands of both training and match play elite youth soccer before discussing measures which may provide a platform to develop talent in academies. Finally, the factors which may affect elite youth soccer players′ long-term development will be observed and subsequently how to ′optimally′ quantify the training and test physical development will be evaluated.

The importance of preparation for optimal soccer performance

The demands of soccer are multifactorial. To perform at the very highest level, an elite soccer player must be physically adept whilst concurrently demonstrating excellent technical and tactical skills. For a player to achieve this, and subsequently positively influence the outcome of the soccer match, it is important that they have a strong physical profile (Wrigley et al,

2012). From the physical perspective, soccer is described as an invasive field game that is characterised by an intermittent activity profile where high-intensity anaerobic efforts are superimposed on a background of aerobic activity (Drust et al., 2000). To be optimally prepared for the demands of the game, the training process which a player is exposed to is vital and must be related to the demands of the game (Reilly et al, 2005).

Demands of soccer

Within the match, at elite first team level, a player may cover a TD of between 9-12 km match (Rampinini et al., 2007; Reily & Thomas, 1976; Rienzi et al., 2000) with approximately 80-90% of this distance spent in low to moderate intensity actions (speeds 0 – 19.8 km. h^{-1}. The remaining 10-20% of the TD is covered in high intensity activities (speeds >19.8 km. h^{-1}) (Carling et al., 2008; Rampinini et al., 2007; Reilly and Thomas, 1976; Rienzi et al., 2000). These distances and relative percentages are widely recognised to be similar within the professional development phase of elite youth soccer (U18-U23s) however, when analysing the youth development phase (U12-U16s) they are significantly lower (Wrigley et al, 2012). Players within the youth development phase have been reported to cover up to 6-8km depending on age groups; U16 covering significantly higher total distances than U12 squads (Harley et al., 2010; Beenham et al, 2017; Castillo et al, 2020). The differences in values are primarily affected by pitch size and duration of games depending on the age group. The 10-20% of total distance covered performing high intensity activities performed by both elite and youth players (speeds >19.8 km. h^{-1}), are commonly regarded the most important to the match outcome. This is due to the notion that these actions are directly linked to the match situations leading to either scoring or preventing goals/goal scoring opportunities (Faude et al., 2012). In addition, frequent alterations in these activities lead to numerous accelerations and decelerations and changes of direction which are also deemed to be an important part of the movements required in the game. For example, a soccer player jumps in the vertical direction an average of 16 times during a match (Reilly & Thomas, 1976), performs up to 36 sprints (Di Salvo et al., 2010) and 50 forceful changes of direction (COD) (Withers et al., 1982). These along with the many unorthodox powerful movements such as tackling, twisting and attempting to maintain or gain possession of the ball while exerting physical force against an opponent (Mohr et al., 2003) also impact on the outcome of the soccer match.

Implications of the demands of the game for talent development

Given the ever-changing demands and requirements of first team professional soccer, it is vital to understand the challenges which face young soccer players at different stages of development. This will allow an understanding of how specific training programmes may optimise their ability to cope with transitions to the first team (MacNamara, 2011). Therefore, it is important for talent development programmes to provide the resources to equip players with the 'tools' they are required to succeed (Lloyd et al, 2015). Although these talent development programmes are ever changing due to the continual progression of soccer, some clubs still consistently produce top level soccer players, perhaps as a result of providing the best resources for coping with future transitions (Al-fermann & Stambulova, 2007). From a physical standpoint, it should be noted that although the players' physical capability may not define a player's importance and impact on the game due to the nature of the sport (i.e. highly technical), but having strong physical characteristics may allow for a player to complete technical actions and impact overall performance to a higher level (Bangsbo, 1994). It seems sensible therefore to have an understanding of the training programmes that are currently within the literature in relation to the physical development of youth soccer players.

To date, neither the evaluation of training load on younger players nor a comparison across a range of age groups to understand the effects of such load has been widely researched. As such an evaluation of the training loads and change in fitness in elite youth soccer players seems sensible to gain an understanding of the programs that are in place to help players get to and maintain the required demands within first team soccer performance. The literature which currently attempts to evaluate youth soccer, currently lacks specific methodology in regard to the long-term development of physical performance (Gil-Rey et al, 2015, Fitzpatrick et al, 2018). Moreover, it seems to evidence the factors which distinguish between elite and sub elite players rather than between-elite subject groups (Rebelo et al, 2012; Brownlee et al, 2018). For instance, it is widely recognised that in regard to the anaerobic demands of youth soccer the ability to sprint fast, move quickly to avoid opposition (agility) and the ability to repeat sprints have been reported as factors that can distinguish between elite and non-elite players (Rebelo et al., 2012), however there is limited research as to how to effectively train and improve this within youth soccer. Furthermore, Brownlee et al, (2018) found that elite

soccer players were stronger than sub elite players in a vertical plane of motion when testing via the isometric mid-thigh pull (IMTP).

The limited research on the training programmes, including the training loads and physical testing completed by elite youth players in development programmes would seem to indicate that most approaches have not been evaluated for effectiveness. Ford et al., (2011) suggest that any recommendations for enhancing physical performance from infant to adult players must be based on empirical evidence. This lack of junior player analysis in regards for long-term development seems surprising as it is well evidenced that long term physical development could be an important part of a player's transition within an academy environment (Lloyd et al, 2014; Burgess & Naughton, 2010). The systematic progression of overall physical load is likely though to be imperative for enhancing physical load. Therefore, it may be essential for enhancing the physical performance, and prevention of overtraining and injury (Matos & Winsley, 2007).

Talent development in youth soccer

The importance of professional playing pathways and talent development programmes is well established in the scientific literature across both individual and team sports (Vaeyens et al., 2008; Burgess & Naughton, 2010; Bergeron et al., 2015; Rongen et al., 2018). Each programme is unique in their structure, although it is well understood that the common goal of any talent development programme is to accelerate the transition from junior to elite level soccer. Burgess and Naughton (2010) state that effective training in talent development programmes work to progressively close the gap between the standards of competition, which could be achieved by developing the skills and qualities that are deemed important to succeed at the senior level (Vaeyens et al., 2008).

Defining talent identification and development

In general, talent development refers to providing the conditions for athletes to accelerate their learning and performance to nurture this identified talent to reach maximal potential (Abbott & Collins, 2004). Talent itself can be defined as '*the outstanding mastery of*

systematically developed abilities (or skills) and knowledge, in at least one field of human activity, to a degree that places an individual at least among the top 10 per cent of age peers who are or have been active in that field or fields' (Gagné, 2004, p.120). Furthermore, the notion of talent development is very closely linked to talent identification which can be defined as *'The process of recognizing and selecting players who show potential to excel at more advanced levels of competition'* (Cobley et al., 2008). The process of identifying potential talent is an important tool in aligning the first team philosophies and subsequent requirements with the academy selection process. It is commonplace for coaches and scouts who are vastly experienced in identifying potential talent to drive the process. From a research perspective, one model which is driving the talent identification process is by the model developed by Williams et al., (2018). This model categorises talent predictors into four corners; physical, physiological, psychological and sociological with researchers aiming to determine whether a variable/ability provides an advantage to the athlete. It is suggested that talented athletes possess innate abilities not expressed by most individuals. Therefore, experienced talent identifiers interpret current performance levels and predict future domain -specific potential to select athletes who will outperform athletes who would not otherwise be identified or selected for talent development programmes.

In terms of developing talent, once they have been identified, many factors may influence an athlete's success which can include: Birthdate, Genetics, Anthropometric & Physiological Factors, Psychological, Birthplace, Support network. It should also be mentioned that a holistic approach should be taken to talent development as recent research has been conducted into the potential predictors of talent in soccer (Reeves, 2018) (*Sociological*, *psychological*, *physiological*, *physical)*. Once these factors are understood and considered, to optimally develop athletes an understanding of the nature of training activities and content is required. In addition, the organisation and quality of the athlete's training should be observed.

The importance of talent development programmes in youth soccer

Once the talent has been identified and placed within development programmes, the combination of high-quality training prescription and increased volume, intensity and duration of training and support from multidisciplinary staff (Cobley et al., 2008). This gives the players the tools they require to reach the top. Specifically, concerning youth soccer, players' development and guidance throughout, the academy system is a priority for the club to maintain their competitive and financial status. As such, clubs selectively invest vast amounts of time and effort into selected players at an early age to provide them with many years of specialist training to develop elite players for their first team. In doing so, clubs aim to persuade the best and most talented players to join their academy program as if they achieve this, the outcome is that clubs breed homegrown players which may reduce the outlay of investment for players from other clubs and potentially sell for profit (e.g. the system in place at Ajax FC in Holland). For this process to be successful though, the initial recruitment must be well thought through for coaches and staff to have the best talent to work with. This talent identification process of youth soccer players has become an essential process within professional clubs and as such received vast attention in sport, exercise and pedagogic literature (Unnithan et al., 2012; 2016; Larkin & Reeves, 2018). As with any initiative there are still limitations to this process. One of the main issues is that there is a consensus that the same measures at senior level cannot be applied to youth ability with several researchers trying explore factors that may allow for successful adult and adolescent sporting performance, including technical (Vaeyens et al., 2006) physical (Ward & Williams, 2003) and psychological (Toering et al., 2009). For example, the notion that bigger/stronger players are usually identified at early age groups, although prior to peak height velocity (PHV) this indication is largely irrelevant (Lloyd et al, 2015). As such, in recent times there has been a move away from coaches choosing players largely based on their physical qualities (Larkin & Reeves, 2018) with more and more evidence attempting to understand the predictors of future talent. However, it is evident that more research needs to be still be completed to understand the specific indicators of future talent in the developing soccer player.

As aforementioned, professional clubs have attempted to create environments for athlete development, aiming to attract the best young players with the goal of producing world-class players (Williams and Reilly, 2000), although measuring 'success' is difficult as each club will

deem success a different way. This will then directly influence the club's philosophy of developing players in their academy system, as one team club might be providing first team players for their own team, another for cup runs, and potentially other clubs might be looking at sell on value of the individual. All in turn are down to the first team managers ideas and beliefs and therefore if a player is at a club with a high turnover of managers this can provide differences in methodologies in short periods of time.

The training process in talent development

Within academy soccer, the training process is deemed central for a successful transition of athletes through elite playing pathways and development programmes (Bergeron et al., 2015). For athletes to advance successfully they must be prepared for the next level of competition from a physical, mental, sociological and technical perspective. All of these factors require specific training to elicit the required physiological, biomechanical, neuromuscular and cognitive adaptations to progress (Young et al., 2001; Hawley, 2008; Reilly et al., 2009; Buchheit et al., 2012; Bujalance-Moreno et al., 2019). It is now recognised that a multi-dimensional approach to talent development (i.e., holistic) is required to account for both internal and external factors (Baker & Horton, 2004). Examples of internal factors include genetics, training and psychological factors, whereas external influences include socio -cultural factors, instructional resources, contextual factors and sport maturity (Baker & Horton, 2004).

Coaches and support staff alike implement programme s to optimise performance levels of the player. One model which seems to be commonly used within elite sport is the long-term athlete development model (LTAD) which aligns training prescription with individual variations in biological maturation, overcoming the flaw of chronological age classification (Balyi & Hamilton, 2004; Lloyd et al., 2015). The model suggests that there exist critical "windows of opportunity" during the developmental years whereby children and adolescents are more sensitive to training-induced adaptation (Balyi & Hamilton, 2004). The same authors also suggest that a failure to use this period efficiently will result in the limitation of the athlete's future potential. This key concept of "windows of opportunities" does however lack empirical evidence (Ford et al, 2011; Lloyd et al, 2015), and perhaps a model which provides a

more inclusive, evidence-based approach to athletic development is the Youth physical development model (Lloyd et al, 2015). Still, with a sole focus on physical athleticism (Lloyd et al., 2015) it limits its application in talent development programmes that require a more multidimensional approach. The programs aimed at developing young players to obtain these traits are designed by technical coaches usually in conjunction with fitness staff. Though typically holistic in nature, these programmes frequently reflect the priorities that the coach viewed as being essential for them to develop into an elite player. For a player to improve from a physical standpoint it is the coach's responsibility to design training to allow for the concurrent development of both technical and physical traits. This is because of the interdependence between the physical and technical and tactical requirements of play and therefore skills and awareness must be developed alongside an appropriate physiological stress.

Operationalising training programs

Talent identification and development programmes are operationalised primarily by coaches within academies, so it seems evident that there is a need to understand coaches' views on talent identification and development. There is currently little understanding of the key stakeholders' perspectives on the long-term development programs and specifically the physical performance of youth soccer players to develop more optimal programmes for the future. An understanding of the views of these key stakeholders in the development of young players would enable insights into the relative importance of physical traits to overall match performance as well as the importance of physical capabilities for games. In elite youth soccer, coaches are always seeking the most effective formula for developing talented young players (Stratton et al., 2005). However, currently we do not know how coaches balance and prioritise the different aspects of the talent development process.

It seems that the characteristics of successful developers (Abbott & Collins, 2004) and the range of influences on the development of Olympic champions have been well researched (Gould et al, 2002). However, the goals and systems for coaching and talent development environments which attempt to optimally achieve the desired characteristics youth players require to transition is less clear. Therefore, appropriate development models must be

prioritised to drive the success of players, by the coaches. Furthermore, attempts to accelerate and maximise these elite junior athlete′s performances represent a key element in professional clubs′ development processes (Ford et al., 2011). It is vital therefore to be able to assess progress to understand the development of a player. Within the literature there seems to be two key methods for doing so and assessing the potential for expert performance: (i) quantitative analyses, which include implementation of multiple test batteries on developing athletes; and (ii) qualitative examination of developmental histories of past or present elite athletes, with methods such as interviews, questionnaires or self-reported, retrospective recall of practice histories (Aquino et al., 2017; Weston et al, 2018).

Coaches may use a combination of both objective and subjective measures to influence the design of their program. Through the use of microtechnology units (e.g. GPS and inertial sensors) the characteristics of match-play at different levels within talent development pathways can be quantified and compared objectively (Bradley et al., 2013; Aquino et al., 2017), which would enable coaches and practitioners to plan and prescribe appropriate training for athlete progression. Currently we do not know what coaches prioritise in relation to their training programs which means that we are unclear on the specific focus that they have specifically regarding the physical development of youth players. Such information would provide a platform for more appropriate physical development programs as part of holistic development programs to be planned and implemented. Given this, talent development programmes and performance pathways, which aim to provide the most appropriate learning environment for athletes′ (Martindale et al., 2007; Vaeyens et al., 2008), play a crucial role in the pursuit of excellence in sport (Vaeyens et al., 2008; Burgess & Naughton, 2010; Bergeron et al., 2015).

Recent research by Orgoran et al., (2020) provided insights into how coaches working in professional youth soccer academies have interpreted, experienced and engaged with the Elite Player Performance plan (EPPP) previously using cyclical interviews to analyse the data. The key information of the Elite player performance plan can be found below:

- The Elite Player Performance Plan (EPPP) is a long-term strategy with the aim of developing more and better homegrown players.

- The EPPP is the result of consultation between the Premier League and its clubs, representatives of the Football League, the Football Association and other key football stakeholders.
- Introduced in 2012 with the mission of producing more and better homegrown players, the plan promotes the empowerment of each individual player through a player-led approach.

(Premier League, 2012)

The EPPP analysis using the aforementioned interviews (Orgoran et al, 2020) highlighted the challenging nature of coaches′ engagement with the policy, more specifically concluding that the intensified nature of participants' work-based tasks, increased accountability of player outcomes, a loss in their professional autonomy and their strategic use of fabrications to represent themselves and their academies in ways to scrutinise their work. Furthermore, it was highlighted that further questions regarding the need to better understand the role of coaches, both technical and physical, especially when undertaking administrative tasks alongside the coaching roles. Christensen (2008) conducted in-depth interviews focussed on the talent identification process of eight Danish national team coaches. The findings indicated coaches valued football skills and personal qualities when making informed judgements on talented players. The coaches regarded game intelligence, practical experiences and sport specific qualities the most important variables when assessing talent in players. Larkin and O′Connor et al. (2012) attempted to identify the specific attributes youth football coaches and scouts considered important when making judgements on youth players. The results indicate coaches and scouts adopt a more holistic multidisciplinary approach to talent identification. Further research is required to investigate the key stakeholders in relation to identifying and nurturing players, to ensure talent identification is not just a process of a player being in the right place, at the right time with the right eye watching.

There is a limited understanding of how the factors considered as important for selecting players are employed. Within English soccer at present there seems to be two very recent developments in junior elite soccer; the academy system audit process which charters for quality and the invention of the elite player performance plan (EPPP), as described above,

which have resulted in developments such as formal coach education. There has been much discussion around understanding what scouts and talent recruiters perceive as talent with Williams and Reilly (2002) examining four key issues: hours in practice, coach-child interaction, parental support and education. In a more recent study, Dowling et al. (2019) examined how professional development phase coaches in the UK work on the development of individual players whilst also focussing on the management of a broader team in a competitive league structure (i.e. Premier League 2). This highlighted the issue with role clarity of the player from stakeholders where it seems to cause a gap between academy and first team environments. To conclude, it is evident that the literature available has not really understood how important the physical stimulus for player development as a whole is to coaches in soccer.

Physical Development

Coaches can work on physical development by manipulating the training and therefore the physical stimulus which is provided to the players. In order to analyse how important coaches, deem physical development, an evaluation of the changes in fitness via systematic testing that associated with their programming should be observed. To do this, firstly an understanding of how to best evaluate fitness and monitor the training that the players are doing is required.

To analyse the impact of training and matches across a chronic period, the training load must be observed. Training load (TL) by definition is as an input variable that is manipulated to elicit a desired training response (Impellizzeri et al., 2005). It has also been well researched that individuals respond to this same training load and in general, physical exercise in different ways (Erskine et al., 2012). However, when individuals are exposed to different exercise stimuli within the same squad, it is important to understand the individual training adaptations that have occurred. For instance, players involved in match play will have a larger physical stimulus imposed on them than those that are not involved (Anderson et al, 2016).

Furthermore, as soccer is a team sport there are further differences in positional demands. It is therefore evident that the differences in TL accumulation between soccer players (Akubat et al., 2012) provides difficulty in ensuring an appropriate level of individual training load is exposed to each player in a team setting. This shows the importance of accurate quantification of the individual responses to external TL is important to optimise physical fitness.

Physical training itself can be defined as a process consisting of a series of physiological stresses that bring about or preserves specific adaptations to enhance a subjects′ ability to tolerate the stressing factors arising from training (Coyle, 1991). However, in contrast to this, according to the principle of training reversibility, the stoppage or marked reduction of training leads to a partial or complete reversal of these adaptations, therefore compromising athletic performance, also known as detraining (Hawley, 2008). In regard to factors which cause training reduction or cessation the following: illness, injury, travel, team selection or vacation may often interfere with an athlete′s training process. These factors should be considered when planning and developing training programs to limit such interferences. Finally, it is often described that when an insufficient training stimulus is prescribed to an individual, maintaining and developing specific cardiovascular and respiratory systems is almost impossible (Mujika, 2000; 2013). An understanding of a player′s physical status is required to understand whether a player is developing or detraining from a physical perspective.

Previous models (Impellizzeri et al., 2005) demonstrated that training outcome is the direct results of the internal load which has been experienced, and in turn, the internal load is directly influenced by the external load which has been administered to the individual. Given that the internal load response is a consequence of the external load completed, it is plausible that these load measures will demonstrate a range of relationships against different training outcomes (Malone et al., 2020). Successful training programmes therefore require the systematic manipulation of key training load variables related to the duration, frequency and intensity of the training stimulus (Bosquet et al., 2007). In order to achieve optimal physiological adaptation, training sessions need to be programmed and adjusted to meet the

requirements of individual athletes (Bompa, 2009). In the current literature available there is little data that attempts to understand the periodisation that occurs within youth players however there are some studies that have focused on elite adult soccer (Malone et al., 2018; Anderson et al., 2016). In addition, in order to understand the demands that a specific training stimulus provides the players, physical testing is required.

Methods of Assessing Physical Development

The player appropriate levels of fitness (e.g. aerobic, speed, strength, agility) to allow them to remain competitive for the match. Recent studies have suggested that age, morphology, and physical fitness are influential parameters of football performance in elite-level football players (Weston et al, 2018) and it seems necessary to understand the physical capabilities of elite youth soccer players as mentioned previously. Physiological and anthropometric tests can provide useful information on the physical capacities of players, including the physiological profile of junior soccer players (Reilly et al., 2000) and where they are in terms of their development in relation to elite players of the same position. To be able to accurately measure physical development within elite youth soccer players, reliable and valid physical performance tests are required. These physical performance tests are usually based upon aerobic and anaerobic capacity, muscle strength, power and functional movement performance under standardised test conditions (Jaric et al., 2005).

An understanding of a player's aerobic performance allows for a greater evaluation of their capability to successfully perform actions within soccer matches to aid the performance of the team. One of the factors that predispose toward a successful professional soccer career is the endurance capacity, particularly intermittent specific endurance (Bangsbo & Michalik 1982; Tesema et al, 2019; Garcia-Pinillos et al, 2017; Francini et al, 2019). In terms of specific tests, Yo-Yo based test derivatives (such as the Intermittent Recovery test level 1) have the strongest correlations with match activity, which could be important in terms of determining effectiveness of a player (0.56–0.77) (Castagna et al, 2009). In addition, specific usefulness has been assessed and confirmed by laboratory measurement of VO2max (Impellizzeri et al, 2012). With a large proportion of the activity in soccer matches is sub-maximal in nature (walking and jogging) and therefore largely stressing the aerobic energy system (Bansgbo,

1994) these tests are useful to implement to track and analyse change in physical fitness.

Previous findings have suggested that a higher accumulation of training at higher intensities, along with increased volume in general, elicits greater adaptations in aerobic fitness. Castagna et al., (2011) reported very large associations between the training time spent at high intensity and the changes in speed at 2 mmol.L^{-1} ($r = 0.84$, $p = 0.001$) and 4 mmol.L^{-1} ($r = 0.65$, $p = 0.001$) of blood lactate after 6 weeks of pre-season training in elite soccer players. In addition, Castagna et al., (2013) found that training spent at high intensity related to changes in maximal oxygen uptake ($r = 0.65$; $p = 0.02$) and Yo-Yo IR1 ($r = 0.66$; $p = 0.01$) after 8 weeks of pre-season training in elite-standard male soccer players. Previous data suggests that improvements in aerobic fitness have been associated with high-speed running in soccer players (Akubat et al., 2012).

As the importance of physical fitness testing in youth soccer players has become more evident over recent years, intermittent tests seem the most appropriate to assess soccer specific endurance, which is why for this thesis we have chosen to use the submax YoYo IE2. Other physiological factors are in turn measured via the use of tests such as the following; sprint testing, including 5 m and up to 30–40 m and COD tests and CMJ tests. As a result, the use of regular physical testing is accepted within elite sports teams and part of a player′s schedule. A better understanding of how these tests can be used to inform and develop practice in youth soccer players long term development is vital.

Quantifying and Monitoring of training load in soccer

TL is commonly known and manipulated via the following factors: intensity, duration and frequency (Impellizeri et al., 2005). Further examination of the TL can then be subdivided into two subsections: internal and external load (see figure 2.1).

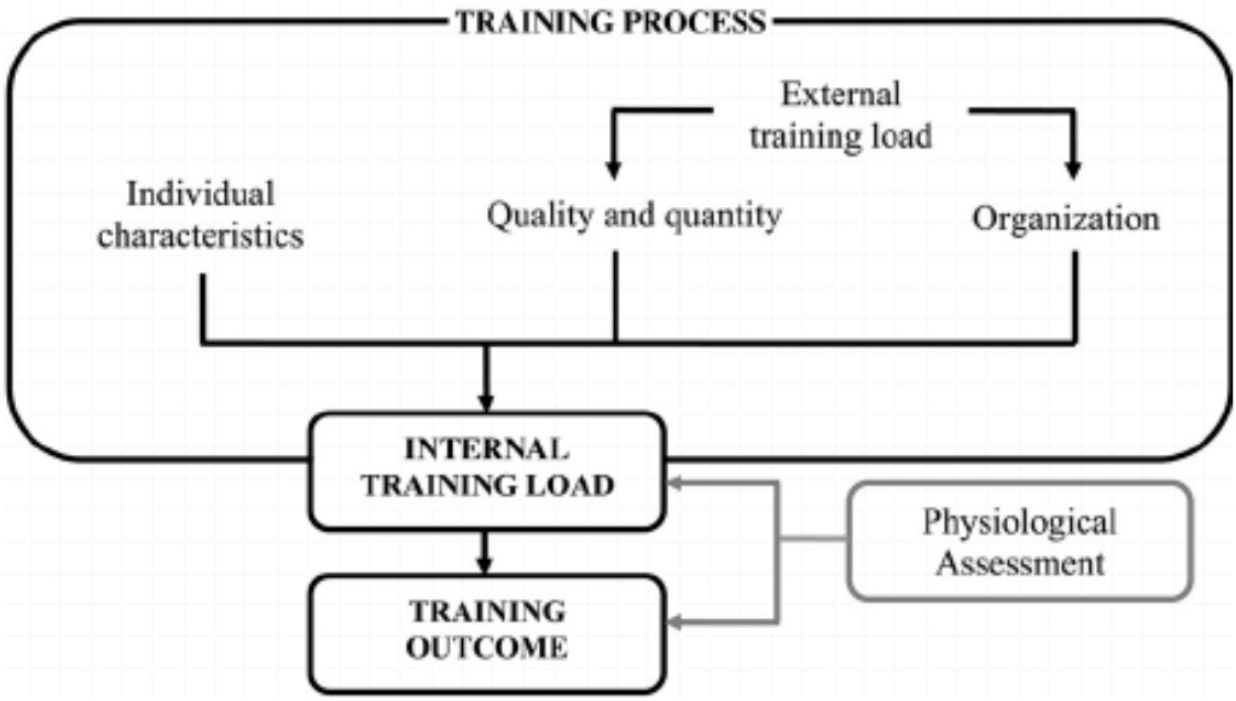


Figure 2.1 Extracted from Impellizzeri et al, 2005. The training outcome is the consequence of the internal training load determined by (1) individual characteristics, such as genetic factors and previous training experience, and (2) the quality, quantity and organization of the external training load.

The external part of training load refers to the specific training prescribed by coaches and practitioners, such as the number of sets/bouts of a drill. The internal training load refers to the physiological stress that is actually imposed on the player. As such, it is this stress (internal load) imposed on the athlete that stimulates the training-induced adaptations produced from the exercise (Bradley et al., 2014). However, it should also be noted that the internal response can be influenced by genetic background and previous training history. Research by Weston et al. (2018) has demonstrated that practitioners most frequent methods to monitor these changes were GPS, RPE, and HR monitors.

The use of these methods to quantify soccer training has helped understand and quantify the following: external training load in the context of periodisation across the training week (Malone et al., 2015; Thorpe et al. 2016); a link between high-speed running and injury risk (Malone et al., 2017b); and dose–response relations between internal load and fitness changes (Castagna et al., 2011; Akubat et al., 2012). It appears the improvement in understanding surrounding training load has allowed for increased performance and

decreased injury risk within soccer players. Quantifying the external and internal loads objectively and subjectively provides the practitioners with crucial information on the individual response to each soccer training session, perhaps indicating the need for individualised training programs to be developed (Bouchard & Rankinen, 2001). A resultant of both the volume and periodisation of these training strategies, the body adapts on a cellular and tissue level. As such, monitoring external loads provides an objective measure to provide the resultant internal load, in turn predicting adaptation. Unlike many linear-based sports such as running and cycling, soccer's multidirectional nature reduces the likelihood that players receive individual specific training loads if not monitored closely. As a result, GPS and HR based technologies have been implemented widely to attempt to quantify the training and match load accurately. Soccer teams have extensively used GPS tracking devices to provide objective measures of external TL. Therefore, the importance of the GPS devices to be both reliable and valid is clear for practitioners working within soccer.

To monitor the internal response of training HR monitors are used to quantify the cardiovascular strain placed on an individual in a response to a given external TL (Drust et al., 2007). The internal response to a given external stimulus can be influenced by factors such as genetic background and previous training experience (Bouchard & Rankinen, 2001). As such, despite its widespread use in sport, there are several limitations associated with heart rate monitoring in sports such as soccer. First of all, there is yet to be a consensus as to the gold standard methodology to determine maximum HR which is used to create heart rate zones for training monitoring. This is due to the current gold standard (i.e. treadmill stress test) not being practical so instead practitioners are reliant on proxy field measures. Issues lie in that the field measure used can therefore vary (e.g. some use the 'hardest session in pre-season', others still use 220-age). Dellal et al, (2012) had previously suggested that it may be beneficial to use field-based tests such as YoYo based derivatives (Krustrup et al., 2003) to calculate HR zones. Overall, the most important aspect of any monitoring tool is to produce reliable and valid data to work with (Hopkins, 2000). Therefore, quantifying the reliability and validity of training load monitoring methods is of utmost importance for soccer practitioners prior to implementing the specific tools into practice.

Previous work has shown mean heart rate after 6 minutes of the submaximal versions of the YoYo IR1 (Gibson et al, 2018) were highly correlated and reproducible against maximal versions of the test providing information suggesting regular testing can be implemented without the players having to work to exhaustion. Within the elite soccer environment, it is not always practically plausible to conduct maximal testing due to scheduling arrangements within the club. For example, periodisation issues may occur, whereby coaches do not want to give up a 'football session' for a fitness test and the subsequent effects of fatigue which a test to exhaustion causes. As such, to still allow for physical testing to occur, previous research has used HR responses to submaximal assessments to gain information relating to the physical status of players, both during exercise and recovery (Bradley et al., 2008). A reduced HR at summation of the test may suggest an improvement in physical capacity with large to very large correlations shown with improvements in both high intensity exercise performance (Bangsbo et al., 2008) and cardiorespiratory fitness (Bucheit et al., 2012). Finally, a study by Markovic and Mikulic, 2014 indicated that the YYIR1 test distinguishes differences among varying age categories and among various playing positions in youth soccer players. At this age, players are highly capable of improving their endurance through the modification of the training and match structure. It seems evident therefore that we need to understand the current strategies that are within the literature to both track and monitor change in aerobic performance.

Adaptive Processes

The monitoring and prescription of training is vital in the achievement of athletic success by ensuring adaptations whilst minimising the risk of injury, illness and non-functional overreaching (Halson, 2014; Vanrenterghem et al., 2017). Given the high training load encountered by youth elite athletes (Phibbs et al., 2018) the balance of training prescription between training modalities (e.g., conditioning, technical-tactical, skills training) is particularly important. Specifically, the physiological development of players is a highly complex process, and adaptation occurs over a long period of time. Due to the long process, periodisation is required to allow for periods of development and periods of recovery/adaptation to soccer. In order to achieve optimal physiological adaptation, training sessions need to be programmed and adjusted to meet the requirements of individual

athletes (Bompa, 2009). The focus of training varies throughout the year; therefore, coaches should ensure that both the individuals and team are receiving adequate training stimuli across the season. This planning is typically organised as the 'annual plan' (Bompa, 2009). In most sports including soccer the annual training plan is usually split into three main phases; preparatory, competitive and transition phases (pre-season, in season and off season (Reilly, 2007). In the current literature available there is little data that attempts to understand the periodisation occurs within youth players however there is some studies that have focused on elite adult soccer (Malone et al., 2018; Anderson et al., 2016).

In terms of the practitioners aims within each phase; it is to optimally prepare their athletes for competition and performance levels across different time points of the season. In pre-season, the aim is to establish the physical, technical and psychological base from which tactical developments can occur (Bompa, 2009). This phase is where the most physiological adaptations occur as a result of the lack of competitive matches allowing for the ability to increase volume and frequency of training allowing for the athlete to adapt to the increased training intensity. This is vastly different from the in-season phase where the focus switches towards the technical/tactical and the main physiological factors are to enable an athlete to be physically prepared for success in competition. These factors include dissipating fatigue and elevating preparedness, maintaining sport-specific fitness and the continued development of technical and tactical knowledge (Bompa 2009). The final phase is generally termed as the off season where an extended period of recovery tends to occur allowing for preparation to the new season to take place. Each phase of the training plan is usually subdivided into smaller blocks of training termed as microcycles, which are typically 3-7 days long (Reilly, 2007) and is structured according to the training objectives, volume, intensity and methods that are the focus of the overall training phase (Bompa, 2009). Microcycles are considered the most important functional planning tool in the overall training process (Stone et al., 2007). Within the given microcycle of a professional soccer player there could be a competitive match once a week and therefore the training load must be adjusted to allow for optimal performance (Impellizeri et al., 2005). In addition, in top teams some players may have to perform a competitive match every 3-4 days, meaning the number of days available for high volume/intensity sessions is limited and the recovery element should be the main

focus. When several microcycles are combined within the macrocycle phase, these phases are referred to as mesocycles (Matveyev, 1981). Mesocycles may typically vary in length from 2 weeks to several months during an annual cycle (Bompa, 2009). For example, a mesocycle could be a 6-week block of training in the pre-season phase where the aim is fitness improvement prior to the start of the competitive season. An understanding of how the physical training should look in each phase to develop a player over a chronic period of time is useful to develop optimal training programmes.

In order for correct programming to be implemented on a chronic level, the fitness coach may require an understanding of the specifics in relation to short-term cardiorespiratory detraining, which is especially important for chapter 5 of this thesis. This notion is usually most evident in highly trained athletes and is defined as a rapid decrease in VO_{2max} decline with most training-induced gains are most often completely reversed when training is stopped for a period longer than 4 weeks (Mujika, 2013). This VO_{2max} loss is predominantly the outcome of an immediate reduction in total blood and plasma volumes. This general loss in cardiorespiratory fitness results in a rapid decline in the trained athletes′ endurance performance. From a metabolic perspective, even short-term detraining is characterised by a higher reliance on carbohydrate as a fuel for exercising muscles. Training programs, specifically when looking to develop a player within an academy setting should limit the periods of detraining.

Factors influencing physical development

The demands of match play and the importance of match involvement for development

Recent research has suggested that match-play is an important stimulus in elite players (Morgans et al., 2014). This is a consequence of the intense nature of the game′s demands when compared to training sessions typically completed by players. These ideas are also supported by data from researchers such as Rhode & Espersen (1987) who analysed the difference in lactate accumulation between match play and training showing lower mean values (2.7mmol-1) in training compared with competition (8.8 mmol-1). This may suggest that competing in match-play regularly is an important component of any strategy to improve the physical status (along with other important components of soccer) of the developing

player.

The differences in load associated between match and training prescription may be challenging for fitness practitioners, as players are likely to receive varied loading patterns depending on their match involvement. Research shows that match play consists of a vast array of exercise intensity (Di Salvo et al., 2007). The prevalence of activities in each intensity is the primary driver of adaptation and therefore soccer players primarily work aerobically during match play (Stolen et al., 2005) with Bangsbo (1994) reporting aerobic energy production accounts for >90% total energy expenditure during a match. This is also supported by research reporting mean and peak heart rates of around 85 and 98% of maximal values, respectively (Krustrup et al., 2005; Mohr et al., 2004). Furthermore, it is well researched that there are differences in VO_{2max} according to playing position, with the highest and lowest mean values in Centre midfield (CM) and Centre back (CB), respectively (Reilly et al., 2000; Stolen et al., 2005). However, low to moderate correlations exist between VO_{2max} and intermittent running capacity (Bangsbo & Lindquist, 1992; Castagna et al., 2003; Aziz et al., 2005), thus some question its importance for elite players (Bradley et al., 2011). Even so, the heart rate values observed in soccer suggest there is an average exercise intensity of approximately 75% of maximal oxygen uptake (VO_{2max}) (Astrand et al., 2003). Due to the nature of the game, where players predominantly work aerobically with high intensity actions interspersed, it seems sensible to develop youth soccer players to be adept across a plethora of physical requirements. For instance, there are a number of activities that demand anaerobic performance, such as sprints, jumps, change of direction, accelerations and decelerations, and tackles (Wisloff et al, 1998). To conclude, it seems evident that the challenge of maintaining and developing squad fitness, in light of the schedule may be difficult from an organisational perspective, and more research is required to understand the best methods to achieve this.

Effect of starting status on physical performance markers

The starting status of a player (starter, fringe or nonstarter) as described by Anderson et al, (2016) often provides a difficult situation for sports scientists with regards to replicating match load for non-starting players to enable maintenance of fitness levels. It is evident that

match load values are far greater than training load values, and evidence suggests that competitive fixtures are vitally important to the overall planning and preparation strategies used within soccer (Malone et al., 2015). It could also be suggested that it is the participation in match play itself that is the most appropriate stimulus for preparing players for the physical demands of match play. For instance, total distance (e.g. < 7 km v ~10-13 km) (Bangsbo et al., 2006), high-speed running distance (e.g. < 300 m v > 900 m) and sprinting distance (e.g. < 150 m v > 200 m) (Di Salvo et al., 2010) is widely varied depending on match or training involvement. This creates a challenge for practitioners to maintain and develop specific aspects of fitness for players who do not start matches and with previous evidence demonstrating significant positive correlations between individual in season playing time and aspects of physical performance including sprint performance and muscle strength (Silva et al., 2011). The effects of long-term match involvement should be required to inform future practice.

Coaches

Firstly, like any team-based sport the coach has the largest say on both the training programme and the overall development of the players. Based both upon their past experiences and opinions the on-pitch load is ultimately decided based on what is best for them to match the players' requirements. In light of this, the coach's role is to determine, along with support staff the micro, meso and macro cycles which potentially influence the adaptations of the players during the training weeks and months (Malone et al., 2015; Akenhead et al., 2016). Along with the planning of sessions, when it comes to delivery, different coaches have different styles of on pitch coach engagement which may elicit different physical responses. This is also replicated in match play, where the coaches will have the final say in formation and styles (Bradley et al., 2013).

Playing Position

There are significant positional differences in physical load observed in soccer match play (Bradley et al., 2009; Bloomfield et al., 2007; Di Salvo et al., 2007; Mohr et al., 2003). As such,

from a physical perspective, playing position will have an impact on the physical stimuli an individual is exposed to and as soccer training is often prescribed as an entire team; players often fall within their own playing position, even when specific drills are administered (Morgans et al., 2014b). For instance, when small-sided games are played within training, but in large spaces, often game like situations will be observed, with players naturally moving to their predominant position. This makes the training load that a player is exposed to naturally relative to the demands of the match, just on a lesser scale. However, when small-sided games are played in small spaces, this may be removed due to the change in organisation of the game (Owen et al, 2004; Beenham et al, 2012). It is evident from previous research that midfielders cover a greater amount of distance in total and in high speed that central defenders, as such the role of the coach can also have an effect on training load as the manipulation of pitch sizes in small-sided games can bring further match like scenarios and therefore, obvious positional differences are likely to occur (Dellal et al., 2012).

Growth and Maturation

It seems necessary to have a strong understanding of the physiological and maturational characteristics that differ across the youth players' development pathway (Elferink-Gemser et al., 2004). This is due to previous research (Coutinho et al., 2016; Coelho e Silva et al., 2010; Vaeyens et al., 2006) which have analysed the qualities that could potentially differentiate between skilled and less skilled youth soccer players. This research suggests that 'skilled' youth soccer players tend to be heavier, taller (Coelho et al., 2010), and faster (Gil et al., 2014) than their less skilled counterparts. With the current methods continuing to rely highly on subjective evaluations by recruitment staff and coaches alike, little valid indicators to measure talent upon their physical qualities have been observed. Due to the multifaceted nature of talent and talent development in conjunction with the need to understand growth and maturation, this has caused some to call for more objective predictors of future potential from a physical perspective (i.e. Larkin & O'Connor, 2017). Recent evidence has suggested that factors such as maturation, hormones and musculoskeletal changes that incur when going through the development phase which have direct impacts on the physical capabilities of youth players and that the training programs which are implemented should account for

these factors in order to optimally cater for development opportunities (Ford et al., 2011). Researchers have also identified relative age effects at elite youth competitions, where older players within the year are likely to be perceived as more talented due to physical advantages. It is therefore recommended that coaches use a holistic multidisciplinary approach to talent development so factors such as physical stature are not overwhelmingly disproportionate when it comes to selection. Researchers have attempted to understand the perceptions and observations of elite youth talent identifiers and the processes and attributes they consider important when identifying and predicting potential future elite players. As soccer is a team sport, body size and strength can give certain advantages that outweigh technical ability in some cases. Therefore, some selection processes have resulted in bias towards the older age players within the same cohort. Furthermore, Williams and Reilly, (2000) have argued that it is the training programs that elite performers are exposed to through their development that is a key factor in reaching the top level of soccer rather than the genetic physiological ability or the differences in maturity status as other research describes. Overall, it should be concluded that both the effects of growth and maturation alongside the systematic training programs are important in terms of physical performance development within junior athletes.

Although there is some evidence to suggest that systematic programming is essential, there is currently limited research, as observed in the systematic review regarding understanding the current literature out there in quantifying training and match load in relation to physical development.

Summary

A review of the literature revealed physical and technical demands are unique to different playing positions and exposure to training and matches, and that individual requirements should be considered when training programs are developed. Specific training methods are proposed to improve overall physical fitness to improve soccer players′ physical performance. Also, the soccer training programs have the potential to simultaneously train physical and technical qualities, although it is currently unknown as to the coaches′ opinions on the relative importance of each factor.

Currently, no information exists in relation to the long-term development of physical fitness across a season for youth soccer players, which accurately tracks training exposure and match status. This information would allow practitioners to understand whether involvement in match play is important for the long-term development of elite youth soccer players. Research indicates players not regularly starting matches may require additional training to develop from a physical standpoint.

Impact of the research findings

In elite soccer environments, the systematic evaluation of applied research findings, and the implementation of research into the practical setting are sparse, due to the nature of the sport. An applied research model for sports sciences has aimed to research whether findings are impactful (Bishop, 2008). Impact itself can be defined as 'as an increase in knowledge and awareness of the research findings of the decision-makers in the environment, as well as changes in decision making practices as a result of the research findings' (Lavis et al., 2003).

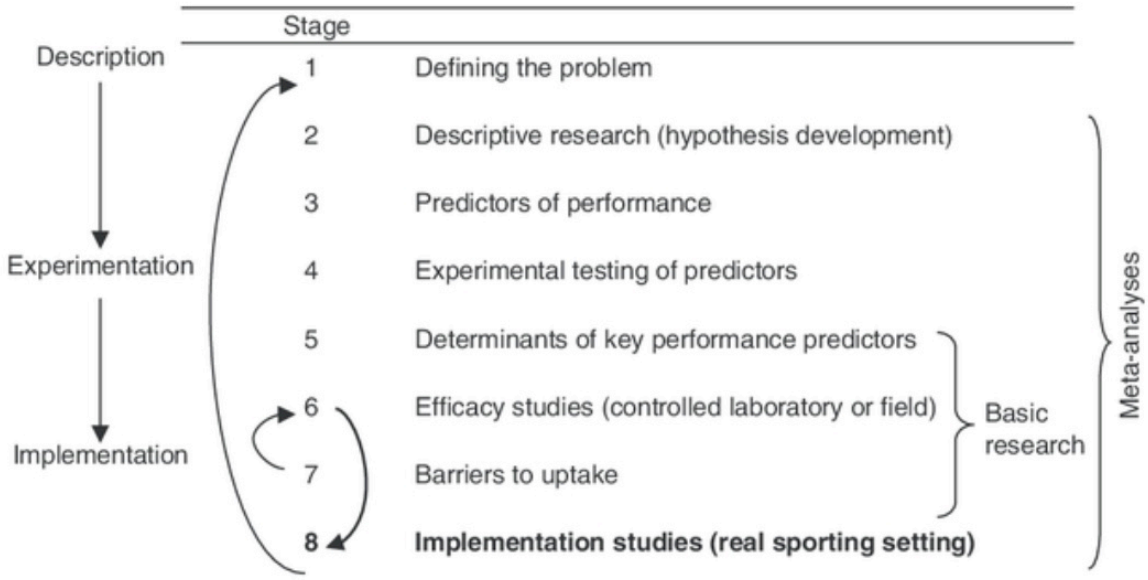


Figure 2.2 Extracted from (Bishop, 2008) An applied research model for the sport sciences. Although depicted as a series of steps, in order for the model to be most effective, it should be seen as a research loop that is iterative and bidirectional and allows for unexpected findings and new research directions to emerge.

This research program aimed to carry out an applied sports science research project to aid and inform evidence-based practice. Firstly, coaches' perspectives on the relative importance of long-term physical development were concluded in chapter 3, which in turn, along with the findings of chapter 4 provided the basis of chapters 5 and 6. Chapter 4 analysed the current training development practices via a systematic review which enabled an up to date understanding of which practices are currently used to track and monitor fitness in elite youth soccer. From this, chapters 5 and 6 were developed, allowing for a longitudinal tracking study to systematically analyse the modulation of match play in the program as a potential tool for physical development, before recommendations to close the gap between starters and non-starters was developed. We believe therefore that this research which was carried out can have a meaningful impact for practitioners, guiding current and future practices in the elite soccer environment. This research was carried out as a researcher (PhD Student) embedded within practice for 3.5 years at a category 1 premier league academy. This club supported the PhD project and therefore alongside the research I carried out the role of an Academy fitness coach at the club. This enabled the development of research questions with coaches and practitioners, as well as many opportunities to feedback the research findings. Given there is now a high prevalence of such positions within sport science and strength and conditioning (Fullagar et al., 2019), it is of interest whether the research carried is impactful through enhancing coach's knowledge and changing coaching practices.

CHAPTER THREE

WHAT ARE COACHES PERSPECTIVES AS TO THE RELATIVE IMPORTANCE OF PHYSICAL DEVELOPMENT TO THE SUCCESS OF ELITE YOUTH SOCCER PLAYERS?

Introduction

In order to understand the training process which has been implemented at the club, it was important to first understand the development process from key stakeholders' perspectives. In doing so an understanding of the relative importance of physical development in youth soccer players training programs was observed. As such, following this chapter, chapter 5 will measure the objective training and match load the players have been exposed to as a result of the training process employed by the coaches. Finally, chapter 6 provides recommendations to improve practices where required.

Soccer success at the highest level has been shown to be highly dependent on various physical, technical, tactical, and psychological factors (Gledhill and Harwood, 2015; Helgerud et al., 2001; Stolen et al., 2005). To date, little research has been conducted that attempts to understand the relative importance of the factors that determine performance in the long-term development of players, specifically the physical element. The limited research, and the lack of knowledge regarding training and match loads completed by elite youth players in tandem with understanding the response to physical load (i.e. fitness changes) in development programmes would indicate that most approaches have not been evaluated for effectiveness (Ford et al, 2011). Developing an age-specific programme which is both appropriate and effective is vital to prepare players when transitioning into the professional game. As the physical demands are relatively well understood at the elite first team level (Bloomfield et al., 2007; Krustrup et al., 2005; Dellal et al., 2011), programmes can be made to ensure the physical qualities required are developed accordingly.

For a player to reach the professional game, a vast array of factors is required to be optimised to allow the developing talent to excel. Developing talent generally refers to the provision of conditions for athletes to accelerate their learning and performance (Abbott and Collins, 2004). This may then allow for the most optimal development environment to be provided in the academy setting. The combination of high-quality training prescription and increased volume, intensity, and duration may be useful to improve specific physical qualities.

To date, most research in the field of talent development has focused on comparing youth players to their successful counterparts and then working back from the elite player characteristics to give a comparison (Reilly et al., 2000; Elferink-Gemser et al., 2004). To understand factors that influence future success in the sport, it seems necessary to understand the characteristics of players both in terms of technical/tactical and physiological capabilities throughout their development from adolescence to adulthood. To reach this elite level at adulthood, it is well reported that to achieve expertise in each sport that youth player must invest many hours of intensive training (Ericsson, 1990). Therefore, understanding the focus of these hours, from practitioners that are an integral part of this training process, is imperative. In addition, there is a wide variety of information on characteristics and behaviours of elite first team level players, however there is little regarding what these individuals were like when they were a developing soccer player. Previous research has (Coutinho et al., 2016; Coelho e Silva et al., 2010; Vaeyens et al., 2006) analysed the qualities that could potentially differentiate between skilled and less-skilled youth soccer players. For example, skilled youth players tend to be heavier, taller (Coelho et al., 2010), and faster (Gil-Rey et al., 2014) than their less-skilled counterparts.

In soccer, the technical coach has a significant influence and control over team and player, including development of personal player characteristics (Amorose, 2007; Cushion, 2010). As such, Weston et al. (2018) conducted questionnaires relating to the importance of training load dependent on job roles within soccer, with question 1 specifically trying to determine who was most responsible for the planning of training. Coaches were mostly responsible for planning training, with sports scientists/fitness coaches somewhat responsible, a responsibility agreed upon. Therefore, it seems evident that the actions of technical coaches significantly impact on the behaviours, cognitions, and affective responses of players, influencing also whether and what they learn and achieve (Cushion, 2010). Further research is required to develop a wider depth of knowledge as to how coach's structure and implement training programs to develop a player from a holistic perspective. Individual coach behaviours reflect their beliefs that usually come from previous experiences, however within a developmental model it seems necessary that all coaches have a concurrent philosophy that drives the same message. It is recommended that coaches use a holistic multidisciplinary

approach to talent identification so factors such as physical stature are not overwhelmingly disproportionate when it comes to selection. Some research has attempted to understand the opinions of elite youth soccer talent identifiers, along with the processes they consider to be important when predicting future successful players (Roberts et al., 2019). They concluded that player positional attributes considered most important in the youth phase are more psychological and technical in comparison with the physiological components. Larkin and O'Connor, (2017) reported similar findings that indicated physiological, anthropometrical and sociological were not qualities emphasised within the talent identification process.

The physiological development of players is highly complex and requires a long period of time to allow for this process. As previously mentioned, the development is focused upon the ability to perform the required technical, tactical and physiological demands of elite adult soccer. Physiological and anthropometric tests can therefore provide useful information on the physical capacities of players, physiological profile of junior soccer players (Reilly et al., 2000) but also where they are in terms of their development in relation to elite players of the same position. As a result of the importance placed on physical development of soccer players in recent times, many clubs now employ fitness and sports science coaches to process, translate and communicate large volumes of training load statistics on player readiness and status to coaches (Akenhead and Nassis, 2016). They are widely seen as a 'consultant' type figure within the training hierarchy, with coaches using them for advice as to how to construct their training programs from a physical perspective. One common trend observed towards sport science is 'low coach buy-in' and therefore practitioners should show an understanding of the coaches' view of sport science and its place in the overall process and also be confident that their primary role is to support the coach (Akenhead and Nassis, 2016). For this to be fully understood and the importance of the systematic progression of training throughout the development phase of soccer training, perceptions and importance of physical training should be understood. In addition, the overall physical load is likely to be essential for enhancing physical load and prevention of overtraining and injury (Matos & Winsley, 2007). However, this may not always be through the systematic inclusion of match play in a player's program. Currently we do not really know how important the physical stimulus is to coaches in football, not just at youth level but at senior level too. Therefore, greater understanding of this will

allow practitioners to more effectively inform and help design practice.

At present, there is little research into the coaches′ values, beliefs and attitudes alongside their overall philosophies with respect to the relative importance of the physical development of youth soccer players compared to development of tactical and technical abilities (Suzuki et al., 2006). Therefore, this study explores the rationale for current training approaches and coach′s perspectives on the relative importance of physical development within athlete development. In addition, it aims is to understand the identification and talent development programs that are implemented within elite youth soccer so that a more appropriate holistic player development programme can be planned and implemented. Furthermore, to understand the clubs plans in how they wish to improve their practices as some of these ideas may not be following the same philosophy. Finally, it aims to gain further insight into the relative importance of physical traits to overall match performance as well as the importance of physical capabilities for games. In addition, an attempt to understand the similarities and differences

Methods

In order to address the aims and objectives of the research question, interpretive research was chosen as it is suited for exploring complex themes through understanding individual experiences and how sense is made of these experiences and actions. It allows for the researchers to gain deep insights into individual issues within a larger social dynamic (Sparkes, 1992), so as such semi-structured interviews were chosen to collect data for this study.

Participants

Four fitness coaches, five technical coaches and one academy director currently based at an academy (Category 1 status) within the highest league of English club soccer were interviewed. The coaches being interviewed had a wealth of experience in coaching (10.2 ± 3.9 years). At the time of interview, the coaches had led and/or held their current role for at least two years. This collection of experience allowed us to understand and produce a comprehensive view of the relative importance of physical development in the overall

development of the elite youth soccer player.

Table 3.1 Participant information regarding years spent coaching, highest qualification and other relevant notes. For the purpose of the study Technical Coaches will be referred to as 'TC' and Physical/Fitness Coaches as 'PC'. The Academy Director will be 'AD'

Name	Years Coaching	Highest Qualification	Other relevant notes
Alan (Academy Director)	16	UEFA Pro	Ex-Player
Ben (Technical Coach)	17	UEFA A Licence	BSc in Sport & Exercise Science
Callum (Technical Coach)	7	UEFA A Licence	Current EFL Manager
Dave (Technical Coach)	15	UEFA A Licence	Previously involved in Performance Analysis
Ewan (Technical Coach)	8	UEFA A Licence	Ex-Player
Frank (Physical Coach)	10	PhD	Over 20 publications in peer reviewed journals
George (Physical Coach)	8	MSc	Previously Head of Fitness In EFL
Henry (Physical Coach)	8	MSc	Previously Head of Fitness In EFL
Issac (Physical Coach)	6	MSc	BASES accredited
Jordan (Technical Coach)	7	UEFA A Licence	BSc In Sport Coaching

Instrument

To achieve a complete understanding of the coach's perspectives on the relative importance of physical development in elite youth soccer players, a qualitative semi-structured interview (see appendix) was chosen as the initial method of inquiry. This type of interview allows for the participants to go into more detail when answering the questions as a conversation flow can develop. Open-ended questions also promote consistent discussion to identify the key attributes participants value when identifying the importance of technical, physiological, anthropometric, psychological and tactical attributes (e.g., How important do you see the physical development in relation to other aspects of player development?). Probing questions were also incorporated to understand why the participant thought this was important (e.g., How important is the match outcome in elite soccer youth soccer; How or do you view this as a modulator for athlete development?).

Procedure

The coaches were initially approached informally and agreed in principle to participate. The formal recruitment process was conducted through the following steps: Participants were initially contacted to gauge their willingness to share their views on the topic. Upon agreeing to participate, participants were informed of the interview protocol and interview guide, including the core questions. The interview guide was developed via a combination of both previous research around the development of youth soccer players, as well as pilot practice interviews and discussions with coaches within the professional development phase. The lead researcher conducted two pilot interviews under the supervision of experienced qualitative researchers. They provided feedback on the process, discussed the order and organisation of questions, and associated probes and follow-up questions. The pilot work was implemented to refine the lines of enquiry and to add in relevant prompting questions to allow for the transition within the interview to be as seamless as possible in the format of semi-structured interviews. The schedule was divided into three areas: 1) Biographical and profile questions;

2) The coaches were asked to explain their views on critical success factors and development processes of elite youth soccer; 3) Considerations purely on the relative importance of physical development of elite youth soccer players. Ten interviews, lasting between 18-45 minutes were conducted via video call on Zoom meetings app (San Jose, California) after initial plans to conduct face-to-face were halted by the 2020 worldwide pandemic. Roller and Lavrakas, (2015) suggested that the inclusion of between 6-12 coaches may be sufficient for offering insights into the research questions. Full ethical approval from the University of Birmingham ethics committee was obtained prior to the study and immediately before the interview began coaches were reminded about purpose, methodology, benefits, discomforts, and risks of participation in the study. All interviews were conducted over a two-week period at the end of the curtailed soccer season. This was a particularly convenient time, due to the club's involvement in the process of reviewing their methodologies in preparation for the resumption of the following season. As such, the style of interviews encouraged coaches to be open about both their personal and clubs' approach towards player development as a whole and more specifically physically.

Data Analysis and Trustworthiness

All interviews were transcribed by the first author with copies of the transcripts offered to the coaches to give them the opportunity to check them over. The first author then proceeded to read each interview transcript twice to allow them to become immersed within the content, with particular attention being made towards the participants thoughts and opinions around physical development within integrated soccer performance, and how different coaches place relative importance on it. Following on from this, thematic content analysis was conducted using Braun and Clarke's six step analysis (Braun and Clarke, 2013). The steps within this process include becoming familiar with the data by rereading transcripts multiple times prior to generating codes systematically. This generates initial lower order themes by sorting the codes into clusters, which then follows by defining and naming global higher order themes, and finally, producing the report with selection of key data extracts. During this process, key quotes were extracted from the data and classified into themes. The qualitative data analysis software Nvivo 12 (QSR International, Melbourne, Australia) was used to

conduct the analysis. To ensure validity and trustworthiness of data, two of the authors performed a collaborative coding process where themes were discussed in each stage of the process to reach a consensus about the organisation and meaning of themes (Auerbach and Silverstein, 2003). A high level of agreement was reached between researchers and minor changes in reorganisation and refinement of themes were required. In addition, a further expert was approached for a meeting and provided feedback around the analysis via a Zoom call. We believe this demonstrates a further level of rigour in our analytical processes.

Results and Discussion

Figure 3.1 Hierarchy of themes extracted from the Interview Schedule

<table>
<tr><td colspan="7">Academy Success</td></tr>
<tr><td colspan="7">Clear Pathway of Development</td></tr>
<tr><td colspan="2">Life outside of football and the player as a person</td><td colspan="3">Individual needs within team environment</td><td colspan="2">Considerations depending on age and stage of development & Development at a young age</td></tr>
<tr><td colspan="7">The importance of winning matches in academy soccer</td></tr>
<tr><td colspan="7">General freshness for match play</td></tr>
<tr><td colspan="3">Playing in a fatigued state while minimising injury risk</td><td>Desire, motivation and resilience</td><td colspan="3">Manipulating challenge points for the greater good & pushing boundaries</td></tr>
<tr><td colspan="7">Coaching Process/Coaching Philosophy</td></tr>
<tr><td colspan="7">The Art of Coaching</td></tr>
<tr><td>Blending Knowledge and multidisciplinary expertise into Practice</td><td>The importance of specific individuals when considering designing whole team practices</td><td>Is objective data important or can a coach use previous experiences to design practice?</td><td>The coach comes first</td><td>Additional Coach responsibilities</td><td>Holistic staff approach</td><td>Is what people think they are doing, reflected in practice?</td></tr>
<tr><td colspan="7">Training Periodisation for player development</td></tr>
<tr><td colspan="7">Session and practice design. How does session design and training periodisation affect the development process</td></tr>
<tr><td>Individual work relating to game specific movement demands</td><td></td><td>Top Ups Post Game</td><td></td><td>Using the game as a training session for development</td><td></td><td>Is training periodisation a hindrance to long-term development</td></tr>
<tr><td colspan="7">Physical Development</td></tr>
<tr><td colspan="7">Relative importance of physical development indicators</td></tr>
<tr><td colspan="2">Objective Data</td><td colspan="2">Importance of gym work</td><td>Measures of physical development</td><td colspan="2">Modified schedules on an individual basis</td></tr>
<tr><td colspan="5">Integrated staff approach to physical development</td></tr>
</table>

General Dimensions, Higher and Lower order themes explored within Stage 2- Critical success factors and development processes of elite youth soccer

Table 3.2 General Dimensions, higher and lower order themes extracted from stage 2 of the interview schedule.

Lower Order Themes	Higher Order Themes	General Dimensions
Life outside of football and the player as a person Individual needs within team environment Considerations depending on age and stage of development & Development at a young age	Clear Academy pathway of development	Academy Success
Playing under fatigue and injury risk Manipulating challenge points for the greater good & Pushing Boundaries Desire, Motivation & Resilience	General freshness for match play	The importance of winning matches in academy soccer
Blending Knowledge and multidisciplinary expertise into Practice The importance of specific individuals when considering designing whole team practices Is objective data important or can a coach use previous experiences to design practice?	The Art of Coaching	Coaching Process/Coaching Philosophy

The coach comes first Additional Coach responsibilities Holistic staff approach Is what people think they are doing, reflected in practice?		
Individual work relating to game specific movement demands Top Ups Post Game Using the game as a training session for development Is training periodisation a hindrance to long-term development	Session and practice design. How does session design and training periodisation affect the development process	Training Periodisation for player development

Academy Success

Success can always be viewed in different ways depending on the perspective and the relative importance that the individuals view it from. The higher order theme which emerged relating to this was overall 'Academy success', with coaches suggesting that this elicits a variety of important factors as follows; The importance that there is a clear academy pathway of development; life outside of football and the considerations depending on age and stage of development; and finally considering the player as a person irrespective of their sporting career.

The first notion of success within elite youth academy soccer was the importance of producing players. This is also examined in a later section in regard to the importance of a player being ready to play for the first team. In this section though, the potential sell on value of a player or the importance of a player who simply makes the first team as a squad player is

discussed. For instance, a player who reaches the first team may potentially relieve the club of a potentially high wage bill of a first team player who would have fulfilled the same role. From the interviews, the director, along with all of the technical and fitness coaches agreed that the number one priority of the academy was to produce players from the academy to the first team. As such, it was also evident that creating a self-sustainable environment in which the club does not require an outlay of large funds of money to bring in a first team player is an important notion. Finally, making back the money that was invested in an academy player by selling them on is also an important feature.

> *My version of success in academies is to produce players.*
> Ewan (TC)
> *Primarily it is getting someone into the first team. But not just the first team, someone that is capable of helping that team who can go in and win trophies!!*
> Alan (AD)

It seems evident from the interviews that a player reaching the first team and the underpinning idea of 'success' from the academy should all be put into perspective and should be relative to the circumstance that the club finds itself in. For instance, competitions the first team are involved in and what league they compete in. Three of the technical coaches were keen to express that a barometer of success might be different from one season to another, and dependent on the success of the first team itself. For instance, one season a really promising group of players in the academy may lose the opportunity to play for the first team due to high levels of success in Europe, however the next season the first team may not qualify and therefore the first team players may play within the domestic cup competitions where potential academy graduates would have previously been required. In addition, if a team goes from a mid-table team to a first division championship side, the standard of player that would be invited to join the given squad would have increased two-fold, factors all of which should be considered when analysing academy success.

> *Measuring success at Academy levels can be quite difficult because it's very circumstantial*
> Ben (TC)
> *What can look like a really positive sort of crop of players. Yeah, they may, you know, may actually only be getting an opportunity because, you know, the first team becomes you know top six rather*

than top four

Dave (TC)

I'm not convinced that's probably the best barometer of your Academy because the situation of the first team has such a massive effect on whether you get players through or not

Callum (TC)

The final theme which emerged on the topic of academy success was the importance of the 'bigger picture', which in other words is developing a well-rounded person, equipped with attributes and skills for a career at any level or environment.

I think the bigger picture is important, I know it sounds a bit corny and all that

Callum (TC)

We'll get one or two through but then also trying to make sure you've generated the experience those lads need going forward to have a professional career.

Issac (PC)

Further comments suggested that the academy system was not a charity and that there were financial considerations that override some of the thought processes, meaning that the sell on value of players is also deemed important. There was an overriding feeling from coaches that a player having a career at any level was a success.

Clear Academy pathway of development

As previously described, an academy requires a pathway structure and clear processes to allow goals to be both achievable and attainable. Coaches highlighted that understanding first team demands was key in developing an effective player pathway and processes.

What are our aims? What do we want to expose these lads to what are the demands at first in football? Because ultimately, that's what we're preparing for.

Issac (PC)

In addition, having the 'best' coaches within the academy set up has allowed for an understanding of not only the importance of technical and tactical development, but also the physical side. Also, coaches highlighted that personal changes in staff should have no or little

effect on the processes that successfully prepare players for the first team. This seems to have been displayed throughout the club as a common philosophy and given a clear structure and process for all staff to work from. Finally, relating to a slightly different notion, the ability to have an academy structure which gives the players the ability to develop holistically, and be well rounded individuals is important for this academy.

> *They (technical coaches) also have a massive appreciation of the physical side, that's just come from having a philosophy within a club and we've been.*
> Frank (PC)
> *Then I think just being able to develop those people to have good conversations with them be thankful for the work that you put into them.*
> Issac (PC)

Considerations depending on age and development stage & Development at a young age

All coaches noted the importance of considering a player's current personal development stage when designing and implementing specific individual programs. Research suggests that how a coach approaches different aged athletes is commonly analysed on a continuum, from coach-directed to athlete directed, with both styles evident to some degree within each cohort (Maclellan et al., 2017). The same study derived three higher order themes; communication, exchanges and interactions; coaching on the basis of the athlete's self-concept; norms goals and expectations for learning within the climate. Within the current interviews it was also evident that the academy director suggested the principles underpinning the coaching methods which are delivered to youth players are the same irrespective of age, however the way in which they are put into practice are different. This links into the 'art of coaching' when understanding your audience is key to allow for the required messages to be delivered effectively to players. Perhaps youth athletes are required to have a coach which is quite direct in nature but still allows for some autonomy to be developed where deemed suitable.

> *That's completely different to how you do it to 19/20 year old – it's the same principle but it's understanding its different in terms of the importance of methodology.*
> Alan (AD)

If you have a lot that's sort of a fantastic technical play, and all of a sudden, the physical side of it becomes a focus for their development.

Henry (PC)

A wide array of ideas were observed within the topic of developing players at a young age; some coaches saw it as a window of opportunity, whereas others saw it as a place to allow players to enjoy soccer and have an emphasis on improving through fun. Therefore, it seems that certain phases of the development process have different objectives or that the focus on certain aspects of the phase are weighted differently. In addition, both technical and tactical coaches were required to work in tandem to provide a fun working environment where appropriate. Coaches were clear to indicate that they did not want players to turn professional too soon although they did see the benefit of the learning adaptations that can occur in the foundation phases of the academy. This was from both a technical and physical understanding that providing them with basic skills and movement patterns at a young age could provide players with an advantage to succeed as a professional player however it was clear that too much could also be a hindrance.

We don't want any 11 to 12 year olds on nutrition and following these programmes. Just let them be kids, don't wrap their whole identity, around the football club, the percentages will show you that. Very, very few are going to make it as footballers,

Callum (TC)

So, I would certainly say at a younger age, I certainly think you've got a real opportunity to, you know, at the real development age of, you know, 910 11, you got a real opportunity to develop some technique.

Ben (TC)

Well in the academy it's different at different phases so when you're younger everything looks a bit different so you probably prioritise technique Of course you can apply it to your senior skill but as you get older I think acquisition plays a little bit less of a part. So, if you're Mo Salah now. How much time do you affect honing a technique, he probably polishing a technique that the minute you're breaking a new technique or starting from scratch.

Alan (AD)

Can you get that foundation of strength into the boys and to prepare them because you're probably not going to do that as much at first in football?

Issac (PC)

Life outside of football & the player as a person

Tactical and physical coaches identified that making a ‘good’ person was important to them, irrespective of their playing ability. Therefore, due to the level of interaction between coaches and players, they felt responsible for shaping a player’s personality outside of their on-pitch performance. This could be considered as individuals’ personal beliefs and values on development and their potential ability to influence and provide important success strategies for the individual. Previous research has identified that four key factors (one of which being the culture of the team and organisation) are key in driving successful team-based environments (Cacioppe, 1999). This was evident within the hierarchy of the soccer club, who described the necessity to create a program that is bigger than just soccer, to allow a player to develop holistically, in order for them to be a credit and represent themselves, the club and their family in the best manner possible. One coach was keen to suggest that the effect of having a player within the squad who is not being effectively developed could in fact be a detriment to the team and perhaps the environment that is created for learning in others (Cacioppe, 1999; Maire Kerrin et al., 2002).

> *We've got the divided, something that's bigger than football that makes sense, the more like, you know, play seems safe. They come in have an enjoyable time.*
>
> Callum (TC)
>
> *We want to make good human beings; people can go out and represent themselves and family and somebody While they will be the club as well.*
>
> Alan (AD)
>
> *I think you’ve got to develop both in team sport, and I think somebody who isn't a well-rounded individual who isn't conscientious or. I say forthcoming coming, probably going to be a detriment to the team environment.*
>
> Callum (TC)
>
> *Players that maybe don't go on another full-time career, but we'll have from the world of science, analysis, making sure that we've got boys that come through the programmes all the way through to have some sort of success in their lives.*
>
> Ewan (TC)

In addition, maximising the potential of an individual was picked out as a key process within youth soccer, specifically their playing ability and their personal development was highlighted.

Success for me in Academy soccer is making sure you maximise the potential of an individual.
Jordan (TC)

Individual Needs within a team setting

A key message from the technical coaches, fitness coaches and the director were that an academy structure which allows for specific individuals to develop within a team setting is vital. One coach stressed that the team and environment created in the club was developed simply to serve specific individuals. For instance, players who are identified as talented and potentially future players for the club are focussed upon in terms of the development program, with the other players within the squad falling within a program based upon these players needs at the forefront of the design. This was evident in the coaches' ideas about academy success, as they reported that getting individuals prepared for a potential first team opportunity was a high priority. Evidence suggests a hierarchy of importance within the squad in terms of a players final potential and the creation of an intense learning environment in which these individuals can survive, rather than developing a 'winning' team at academy level. In addition, through testing and subjective opinions, coaches analyse both the strengths and weaknesses of the individuals to strategize a plan in which the player can either enhance areas to improve, or further develop areas of strength. Identifying these areas can be complex and does not just simply rely on objective data such as sprint scores or their pass completion within a game, it is the interaction between all relevant factors of success. One technical coach even suggests that if playing within a game may be detrimental to their long-term development, possibly due to injury risk, then they would be more than happy for that individual to be removed for the game even if that consequently meant the team may lose the given match.

What's going to be their super strength, that's going to make a premier league footballer, and then what's his weaknesses? And then we can try and chip away and just try and divvy up between the staff as best as best we can, really.
Issac (PC)
Its an impossible question to answer because if you're talking about someone that is genetically blessed and is already an amazing athlete. Yeah, then it's probably a bigger priority. If there is a

strong. If they're being able to sort of decide that the best human genetics points, physically they're already a gifted athlete then of course they can improve that might not be as important as if they can't track the ball or pass the ball or finish or whatever position. They have, they're actually not as important as the others, all I think that its c completely up how important the physical part is depending on the person that you're working with.

Alan (AD)

From an individual point of view is constantly looking at what the outstanding corner is and trying to enhance it, and then in the same breath is what's the weakest corner and making sure that's our way before sure that we're less than down,

Ewan (TC)

The team is just the team is just there to serve the individuals. That's it.

Jordan (TC)

So it's not ideal to miss training but if if you know that that's that's really important to him and you all agree some more than a point of view that's focused and if that means that that change and then puts him at a slight disadvantage when you go into playing the game and I don't really see that as being an issue,

Dave (TC

Importance of winning matches in academy soccer

Every elite coach and athlete ultimately want to become the best and emerge successful against their opponent. As such it seems there is a common notion that success equates directly to winning and therefore failure with losing. However, within a developmental model, as opposed to the win at all costs and profit-oriented model that characterises high-level college and professional sports, the measure of success seems to go beyond individual statistics and team standings. Previous research has described that between 18-21, the aim of soccer is to provide 'an environment where they can learn to win and 'replicate the professional game' (Bugess et al., 2010). Within this developmental model it seems that success is as a result of giving maximum effort, working to develop one's skills, and enjoying the social and competitive aspects of the sport experience (Smoll & Smith, 2005). In contrast it has been suggested that at approximately 18 years, athletes enter a 'training to win' phase where the focus turns to optimising performance (Relvas et al., 2015). Perhaps currently we are not good at measuring this and this could be an area more research should be focused on in the future. This model therefore suggests that youth players within it can learn valuable lessons from both winning and losing along with merely taking part. Therefore, within youth soccer, the outcome of competitive match play may not always be the main priority due to the developmental nature of academies. Potentially a more structured approach across the technical, tactical, and physical requirements of training, may be required to plan for both development and match readiness to be concurrently optimised.

In contrast, it would be naïve to think that winning is not an important part of the learning process within academy soccer. Previous research stated that winning is an inherent part of competition and therefore an important goal, but it is not the only or the most important objective (Smith & Smoll, 2002). As such, it is imperative, and perhaps the primary goal of youth soccer training programs to have a program which develops the player holistically, in addition to the technical and physical demands they are required to perform within the match. In summary, winning should be observed as part of the athlete's development but not the primary focus.

In short, winning should be viewed as a consequence of the athlete's physical and psychological development and not the primary focus of athletic involvement.

> *It always matters, it matters to the kids, it matters to the coach I have a sliding scale*
> Alan (AD)
> *ultimately, they will be judged on it*
> George (PC)
> *As the boys get older, I certainly think the outcome has responsibility that come with it a resource of responsibility.*
> Ben (TC)
> *The older you get, the more important it gets. I don't think there's any point in producing players who have not had to manage a game or play to win.*
> Henry (PC)

The coaches largely agreed with the notion that during the development phase of soccer the match is not that important, however a common theme was that as you get older the outcome does gradually become more important. They all suggest that winning is important to a point, but on a "sliding scale", and that it is not necessarily the result itself which is important but the surrounding aspects of success that winning brings. For instance, one coach said it is a lot easier to convey effective messages when a team is consistently winning which can only aid development and performance. Further analysis is required as to how coaches employ strategies in relation to physical development from a match involvement perspective to try and understand if these coaches are actually trying to win games by consistently picking their 'best team' or not. The quotes below seem to suggest within the academy, and especially the professional development phase, that the match is viewed as another training session. Therefore, contextual factors might influence the ability to develop physical attributes depending on the objective or phase of their development. The result is described as important but ultimately it is the way the results is achieved, perhaps in line with club philosophies that is even more vital.

> *The match is just an extensive training. It gets a little bit more important. The higher you go, obviously, yeah. The emphasis should be on the performance, the process.*
> Frank (PC)
> *Probably how you get there is.*

Callum (TC)

In addition, one example described an academy players performance in an important FA youth cup match from a few seasons' prior. They described the player in question was playing up a year and having an extremely tough game. Instead of changing the player at half time, the coach gave him the opportunity to make it 'right' and play in the second half to overcome the challenge that was presented to them. This may not have been the most effective strategy to try and win the game, however it was a pivotal moment for the players development.

> *The easy thing would have been right experienced player right back but no, he actually said I want to see how you're going to cope.*
> Dave (TC)

General Freshness for match play

In relation to the importance of match outcome, another theme which emerged was the notion of fatigue in relation to match play. Coaches claimed they did not mind if players were participating in matches under slight fatigue due to the outcome being less important than at elite first team soccer. For example, coaches mention that the game can be seen as an extension of training, with further perspectives suggesting that when playing elite first team soccer the demands mean you are rarely ever fully fresh for match play. Morgans et al., (2018) suggests that the match is the most important day regarding physical stimuli during the week, perhaps suggesting the systematic involvement in match play is actually a good strategy or training principle to allow for physical development to be seen

> *I don't mind if they are fatigued going into games. For me, that's really important as fitness coaches, because you know that you can push them a bit harder in training.*
> Callum (TC)

Playing in a fatigued state while minimising injury risk

One theme that coaches highlighted was related to players competing under fatigue because they believed it facilitated development and was a requirement of pushing players

boundaries. However, technical and physical coaches agreed unanimously that fatigue states should be used cautiously so that injury risk is reduced. Coaches accepted that exposing players to fatigue would build tolerance to the performance demands, however they were keen that it did not lead to injury. As such this denotes that the most important thing for developing soccer players abilities is to play soccer and if they are injured, they are missing key time within their development journey.

> *it's the skill of the practitioners to make sure that's dosed in the right the right way to limit the amount of risk of injury, but they'll also like to drive performance*
> Frank (PC)
> *as long as the lads are safe to do show that we should be overreaching and then sometimes guide into again potentially fatigue, to try and build that robustness and the price tolerance inability to cope with that sort of load and weekly structure.*
> Issac (PC)

Multiple coaches stated that it was important for young players to be exposed to playing matches under fatigue which would provide another learning opportunity to experience what the demands of adult soccer may look like. For instance, Mohr et al., (2011) concluded that fatigue occurred towards the end of matches as well as at temporarily during the game, independently of competitive standard and of team position. This highlights player will fatigue during soccer performance and that preparing youth soccer players to cope with this seems sensible. In addition to this, Russell et al., (2011) analysed the effects of fatigue on soccer skills performed during a soccer match simulation, with findings demonstrating that the soccer specific exercise negatively influenced the quality in gross motor skills, such as passing and shooting. One coach within the professional development phase alluded that they actually enter multiple competitions just to provide the players with this experience, not necessarily to be successful in winning it.

> *That's why we read in all those competitions and season because they have to get used to playing under fatigue*
> Callum (TC)

Manipulating challenge points for the greater good

Previous psychological based research has described the predictor variables measured in the initial phase of the career of a unique group of highly skilled adolescent youth players from a soccer academy of high international repute, and career success was assessed 15 years later. Success was defined as playing for a Premier League soccer team in a European competition for at least ten years in the 15-year period following data collection (Szymanksi & Zimbalist, 2005). In order to successfully progress into elite soccer, it seems key to engage in tough physical and mental effort (such as effective coping with stressful situations). This type of activity can only be sustained for a limited time per session and per week without overreaching occurring, therefore periodisation of the challenge should occur. All of the coaches within this interview believe that it is important within an academy environment to push players boundaries, both physically and mentally, to give them the best chance of achieving success in the future. Considerations of when this occurs within their program should be made though.

> *We have to ensure that we give them sufficient time where they're playing under fatigued where they are being pushed physically, where they understand that they're going to go into games and not feel that that's not the world they're going into for them to go into games and feel tired and fatigued and find a way to get through it is really important, physically and mentally as well.*
> Ewan (TC)
> *They do also need to play against opposition superior and they need to be outplayed, be helpless in terms of physical stature. They then can overcome those disappointments, and this can be massive in terms of their development.*
> Frank (PC)
> *They have to be as fit as they can be, they have to be right on top of their game, their nutrition strategy, because if they're not, they won't be able to compete with those physical freaks out there.*
> Callum (TC)
> *I guess, what are people's boundaries? Is it a metric that flags up red on a spreadsheet or ultimately could he push himself further and harder?*
> Issac (PC)

One coach did provide an interesting point of pushing players boundaries, considering trying to understand what these boundaries are. Relating previously to the art of coaching, this denotes the difficulty that coaches have within the development process. The concept of

pushing boundaries for all development aspects. For instance, this demonstrates how you can potentially manipulate constraints to develop specific attributes by changing loads in the gym for instance but by also creating these increased loads and demands in game like environments (i.e., competition games, SSGs or friendly matches). A key aspect that was extracted from the interviews, and which relates closely to the success of the academy which will be discussed in more detail in the following section, was the importance of making a player ready for the demands of first team. This is not just regarding the on-pitch performances, but also the surroundings and settings that the player will be exposed to. The academy director was keen to state that it is not just about the player reaching the first team squad, it is about the player being a key feature within the starting team who can help the club, win trophies. This has been the philosophy of the given club for a number of years and allows for the club to be sustainable and produce players of high-quality year after year. Ensuring a player is ready for the first team environment, shows the importance of all the other themes which have been explored in these interviews so far; playing under fatigue, importance of winning matches, desire and resilience. The overall development program of the academy is set up to allow for the player to have an effective learning experience to have the best chance at being successful at first team level.

> *Someone that is capable of helping that team who can go in and win trophies!!*
> Alan (AD)
> *The first team of which ever academy it is*
> Ewan (TC)

Reaching the first team and being successful will also require the player to be exposed to some setbacks to overcome along the way. One of which may be playing against a team of higher quality players. The result therefore may not be important to the coach in this instance, more so the manner in which the player in question performs and copes with the challenge.

> *He really wouldn't say that the outcome of the game is important. Yeah, you know, so it is really about like how the team played How did they do?. How do the individual players do. The results will come secondary. I do think though when you play certain opposition so wherever it's like I say, I manage the city or you want to see how your base compete against the better players. Yeah, but then again that's*

not the result. So, if we out payment city and lose three one.

Frank (PC)

Desire, Motivation and Resilience

There is an increased demand on players in relation to both the physical and mental requirements which is placed upon them. As such, some athletes succeed or fail not necessarily solely based upon their technical and tactical capabilities. The difference between successful and unsuccessful athletes can often be understood via their behavioural traits. Successful athletes have been known to set long and short-term goals that are realistic, measurable and time orientated. As such they are aware of their current performance and what they need to do to reach the next level.

If you're trying to develop physical, you're also developing mental, for me it all links. In reality it's hugely important like the mentality and the desire will ultimately be overriding if you have got that then you won't become a professional player.

Frank (PC)

You've got a generic program which players work within, and then you will have players who will fall away from that due to the lack of mental desire.

Callum (TC)

It seems evident that both the technical and physical coaches agree on the concept that players require the mental desire in order to be able to achieve their goals. As this is a shared value it seems that coaches will work in unison to develop these traits and therefore this positively impacts the designing and scheduling of their programs. In addition, coaches reported that habits and formation of behaviours can be key in talent development and it is the coach′s responsibility to create and enforce the social culture. Key themes that emerged from the interviews were that desire, motivation and resilience were all important traits to build upon if player was going to become successful at elite level of soccer. In addition, some of them stated that it was important that players had a high level of autonomy to allow for them to develop.

I think a lot of the habits and parts of the culture that we've got right we've certainly not cracked it, but I think we're a lot closer than what we were certainly when I joined

Jordan (TC)

Coaching Process

Actions, beliefs, traditions, and perspectives that define how we live in the world also define how we live and learn in sport. (Schempp, 1998). The process in which a player evolves from joining an academy development program to leaving, whether that be into the first team or another club or potentially leaving altogether (deselection from academy program), is partly to do with the environmental factors which the player has been exposed to. A major part of this is the coaches and the processes frameworks in which these coaches work. Nesti and Sulley, (2012) whose work is specifically concerned with applied practice in football, argue coaches' philosophies at the best football clubs are always player- centred. However, player-centred does not necessarily mean the experience is any 'softer' or 'easier' for players. For example, there is a curriculum to deliver but the process of how you do that is built by all relevant key stakeholders. This is what this study is trying to understand from a very specific focus on the physical corner. Findings within these interviews show that coaches often referred to both the 'art of coaching' and the importance of being able to blend knowledge into practice when explaining their opinions on their specific coaching process. Previous research (Cushion, 2007) highlights the need for more research relating specifically into the coaching process and coach effectiveness. Furthermore, the subjective perception of coaches' thoughts on athletes and how they can impact their performance both individually and collectively.

The art of coaching

Coaching has been previously described as "a relational, dynamic social microcosm" (Cushion, 2007, p.397), which involves complex layers of interaction and interdependence in particular contexts. The coaching process involves both coaches and athletes and the ability to create good relationships to allow for ideas to be conveyed and delivered effectively to the athlete is of upmost importance. As the coach's role is to somewhat oversee the holistic development

of an athlete, the long-term development programmes and the way in which they are delivered to the athlete seem an important factor for player development. For instance, the ability of the coach to devise an environment that allows for optimal learning is a key to the success of an athlete's development. This takes meticulous planning of practice with Voss et al., (1983) finding that expert coaches spent more time planning practices than non-expert counterparts with an emphasis on long-term goals rather than singular sessions. As such, the structure of training and the specific knowledge of coaches involved in the process of planning is imperative to the development of players. There have been conflicting arguments surrounding evidence which is deemed to attribute as the predictors of future success (i.e. physical, sociological, technical and tactical) but it seems a blend of all may be the best strategy as this interview demonstrates.

Blending knowledge and multidisciplinary expertise into practice

Findings showed that technical coaches referred to the importance of understanding each element of development (i.e., physical, psychological), with an important aspect of a technical coach role to be able to understand all of the information they have received and blend it into effective delivery of a training session. In the past, sport scientists and psychologists have made efforts to find out the successful elite coaching behaviours in relation to peak performance in the competitive sports arena (Bloom et al., 1999). For example, Bennie, (2010), used cross-case analysis of three Australian sport teams and concluded that effective coaching involves the use of key social skills, personal characteristics, and organizational expertise. Mark Bridgewater described one aspect of the technical coaches' role:

> *My role is to is to take the information that's given and put that into the, into the picture that I have in terms of the development and to work out If it's viable if it's the right thing.*
> Ewan (TC)

This was supported by another technical coach within the academy, who added that you have to blend everything into one to create a program that allows for the player to have the best chance of success when they leave. In addition to this, support staff (fitness coaches) that were interviewed also believed that it was the coach's role to take information that is given to

them and provide what they believe to be the best practice for the players. A common belief is therefore understood that using expert's knowledge to allow for more informed coaching decisions to be made is key for the success of the athlete.

> *In terms of the art of the coaching, it is trying to pick up all the different skills from the sports scientist or psychologists, try to blend that into a session*
> Issac (PC)

It seems evident therefore that as a technical coach, working with someone with good knowledge in their subject area and ultimately, a good working relationship with their assistants is imperative to the coaching process. Cote & Samela, (1996) found that expert coaches chose to work with assistants that were competent, hardworking, and trustworthy, in addition to being highly compatible with other team members and playing staff.

Holistic staff approach

Although the responses seen within the previous sections provide evidence that it is clear the coach ultimately has the final say with specific decision-making responsibilities and that there is a hierarchy process in which decisions are made, it does seem that there is an open environment where healthy discussions can be had. The technical coaches believe that they are approachable, and that they have discussions prior to every training session to decide on appropriate design and structure. In addition to this, it seems the fitness coaches are happy that they know they are support staff which contribute, but do not have the final say, with one coach discussing that they believe the technical coaches have a great understanding of the physical corner so sessions usually allow for physical development. It seems like there is a clear philosophy within this club that strives for player development and therefore stops the somewhat egotistical views of practitioners getting in the way of this. This positive multidisciplinary team (MDT) working environment has been previously researched with effective and positive influences on player development when MDT provide competition, conflict but also strive to develop practices alongside one another. (Bell & Kozlowski, 2002b).

Yeah, I'd like to think that as a member of our group of staff that they could approach me and say, can we incorporate this into today's session. It's really important that you can come to me and give me a thought about the session.

Ewan (TC)

At this club but something in the past as well if, we go back to the other areas I think it's important that strength and fitness in s&c coach performance coaches whatever you want to call is that we understand what our role is. We are support staff ultimately.

Henry (PC)

we will Converse prior to every session

Jordan (TC)

Holistic approach, it's not like we work in isolation to the coaches. They also have a massive appreciation of the physical so yeah, that's just come from like having a philosophy within a club and we've been.

Frank (PC)

So we come up with what the initial kind of a session would be, he would he was quite good in terms of understanding that that those days and what each one should sort of incorporate so he would usually come up with something. And then, Jack would obviously help, sometimes around you know volume and how many sets we're going to do

Dave (TC)

The importance of individuals when considering designing whole team practices.

In addition to the knowledge and understanding of the game that a coach requires in order for the effective design and implementation of practices to develop the players, there also has to be a consideration of the specific individuals that are within such team. Several coaches reported that the individual is more important than the team within a development program, as it seems coaches believe a player making it to the first team or having "sell on value" is more important than a under 18 team for example winning a league or cup. In other words, having a successful team is important but the individual requirement vastly outweighs this, resulting in the requirement of individual training practices to be embedded.

There are loads of different individuals within that who have got different needs. For example, he (coach) would always say to me, there is a physical side of it, how can we get that in the game first?

Issac (PC)

Further to the notion of above in which describes the importance of the assistants, Issac described how a coach would use experts to help design practices to develop the specific weak areas for individuals. The process of asking an expert, with the assistant understanding that they also have an important part to play within the development process, demonstrates that a good team environment is embedded within the staffing structure, with individual player development a number one priority.

Is objective data important or can a coach use previous experiences to design practice?

When questioned about objective data, and the role it can play within youth soccer player development, there was a wide array of feedback in terms of the way it should be used. The general consensus however was that it seemed to lack importance and that previous experiences, feedback from first team coaches and the 'feel' of coaching practices were much more important, with objective data merely adding numbers to thought processes.

> *I've always considered football more as an art rather than a science. It's not an Objective Science.*
> Alan (AD)
> *I think a lot of mine goes off previous injury history and feel.*
> George (PC)
> *It's very much like when they go up to the first team, what is the feedback from football coaches and fitness coaches*
> Frank (TC)

There seems a consensus that measures that come away from objective data seem to be more important to the coach regarding designing practice and developing players. This follows in line with previous research by Arcos et al, (2017) who described the training loads experienced by players are often the consequence of coach-planned training. This seems to be through the understanding of 'feel' and the coaches good understanding on what is important on such day potentially through gut, intuition or simply their expertise. Perhaps this is due to the experience of the cohort of coaches in the sample (see figure) and if less experienced coaches and practitioners were interviewed a more data driven objective approach would have been observed. As such it seems the objective data is not there to

prescribe practice, it is just in place to give some information that aids in the decision-making process. There is still a subjective component, and it seems coaches really want to use both a combination of objective and subjective information in any decision-making process.

Another key aspect that seemed to arise through the questions relating to the importance of physical data was that the data needs to be highly contextualised in order to it be relevant and for assumptions to be made from it. In other words, it is how is this data meaningful and relevant so that it can help develop players.

> *That's all got to be related to the game that they play. So, you can't just look at the data and say he has covered less ground in the game which he's winning 6-0 as he doesn't have to run*
> Ewan (TC)

Is what people think they are doing, reflected in practice?

An important point of note was highlighted by one of the fitness coaches, who suggested that perhaps some members of the coaching staff may not actually use the other members of staff, or objective data when considering the design of practices and sessions, rather use their own intuition. This may be a potential limiting factor in creating an environment in where all aspects of development can concurrently be improved. Furthermore, an understanding as to the reasons that are blocking this, perhaps it is the notion of not contextualising data or perhaps it is something to do with the power dynamics which are employed clubs. It therefore seems important that packaging relevant feedback and information which can then be included in decision making processes when using tactical periodisation for example and training sessions so that they have a primary technical and tactical objective but also can hit some secondary aims surrounding the physical area also.

> *If you ask everybody in a group setting. Everybody would have an agreement that there is appreciation for the physicality of the game. But I don't think that's always reflected in the way that people construct sessions or what they prioritise. Sometimes that could be due to a lack of education around it. Other times I think it's due to just a change in in priorities, or, essentially what excites people.*

George (PC)

The coach comes first

Similarly, to the findings within blending knowledge into practice section, there is a clear hierarchy within the development process in which the technical coach will ultimately have the final say, in line with the academy director's philosophy, on team and player-based sessions. It seems evident that support staff such as fitness coaches and physiotherapists have a part to play as a consultant-like figure, but ultimately as a figure to give professional advice for the technical coach to digest, interpret and implement into practice. Therefore, having a clear, and good working relationship where individual roles are understood seems evident for a strong player development environment.

> *The coach will always have the final say. And in terms of the art of the coach, is trying to pick up all these different skills from the sports scientist or the physical side or psychologists*
> Issac (PC)
> *It is coach led but the sports the fitness coach was, of course, part of the consultation maybe or could give advice.*
> Alan (AD)

Additional coach responsibilities

When the coaches were asked whether they felt if they were developing players or people, the majority of coaches instantaneously spoke about the importance of developing good people. With the vast number of hours that coaches spend with players, that they have a key role in moulding the players personality and developing non-soccer related characteristics. The academy director, did however, want to reiterate how important that developing these soccer players are as players is, especially when they turn professional during the professional development phase, as ultimately being a soccer player is their job and the club is required to show a profit as it is a business. Finally, some coaches reported, that they do not ever take the place of the parents however they do become a figure in which they have a large impact on players behaviours both on and off the field.

I don't think we ever take the place of, of the parents. And obviously, I've been very fortunate, you know, through careers in terms of teaching and the Academy, work with some really good kids

Ben (TC)

But I do think we as practitioners have a responsibility to develop a well-rounded individual within that approach.

George (PC)

you are doing really is providing the players with an opportunity, a platform to come in and develop a playing football, like football play football.

Callum (TC)

Training Periodisation for player development

The management of training load is traditionally considered in weekly microcycles consisting of one game per week (i.e. Saturday-to-Saturday schedule), though it is noteworthy that elite soccer players often play two (e.g. Sunday-to-Saturday) or three (e.g. Sunday-Wednesday-Saturday) games in a seven-day period (Malone et al., 2016). This is largely due to involvement in numerous competitions (i.e. domestic league/cup competitions and European competitions) and periods of intense fixture schedules such as the winter period (Morgans, 2015). These situations require practitioners to carefully plan and manage the training load to concurrently provide optimal match day performance levels, recovery (Morgans et al., 2014; Nédélec et al., 2014), whilst also preventing injury (Dupont et al., 2010) and symptoms of over -training (Morgans, et al., 2014). Within youth soccer, the outcome of competitive match play may not always be the main priority due to the developmental nature of academies. Therefore, it is imperative for practitioners to evaluate the demands associated with any given period of training and matches to provide appropriate individualisation of training and match load for each player's development needs.

How does session design and training periodisation affect the development process?

Coaches and fitness coaches alike, were keen to exaggerate the requirement for a different physical stimulus on different days, although stressing a first team tactical periodisation may not be the most effective approach within a developmental program of youth soccer. This demonstrates the thought processes of coaches; that winning on a Saturday may not be

number one priority for coaches and staff, as the session and practice design does not always reflect a model in which would allow for optimal match day performance. There is however a consideration as to the physiological demands of soccer and coaches were keen to stress that the demands of each session should be relevant to the days away from the game due to potential risk of fatigue and recovery. Another key point arose which showed the importance of not using a tactical periodisation model, in that the under 18s squad frequently go to college on a Thursday, therefore losing a training day. The coach stated that 'If you do not treat a Friday session as a training day and use it instead for match preparation there is potential that the players may only be exposed to two hard physical training days per week'. In relation to the specifics of each session, the coaches stated that they have an emphasis on the technical and tactical work they deem important to gain from the session, before input from the MDT allows for specific physiological stressors to be achieved.

> *Yeah, it was just the emphasis changes depending on where you are in the week, and where you are in terms of your games programme.*
> Callum (TC)
> *Suppose it depends on the day.*
> Issac (PC)
> *I think each day has probably got a different physical component that you need to. It doesn't necessarily have to be a tactical periodization model*
> Dave (TC)
> *Then you say, okay, Wednesday, Thursday, Tuesday, Wednesday, they're going to get a hit. It's a Thursday they're college and won't do anything then Friday they're preparing for a game then they'd only have two training sessions.*
> George (PC)

Using the game as a training session for development

With recent research suggesting that match-play is an important stimulus in elite players (Morgans et al., 2018) it seems that for outfield players, who play full matches, the match days typically represent the most physically demands days within a micro cycle (Di Salvo et al., 2007). Understanding the specific physical demands of match play is important to optimise the training process, as specific protocols and sessions can then be designed in line with these

demands (Di Salvo et al., 2007). Anderson et al, (2016) found that when teams are required to participate within multiple matches per week (2 or 3 matches in a week) the match-day may account for up to >95% of a squad's high-speed running (HSR) and sprint distance (SPR). This may suggest that competing in games on a regular basis is an important component of any strategy to improve the physical status of the player with further observations highlighting the potential for sub optimal loading patterns regarding partial-match or non-selected soccer players. In relation to development of the players it seems evident that for physical development the systematic participation in matches seems important.

Top Ups after the game

Literature suggests that training sessions within a periodized micro-cycle may fail to deliver match equivalent load measures such as TD, HSR and metabolic load (Morgans et al., 2018). As such, consequences of the lack of stimulus to ensure that players are adequately conditioned in preparation for potential match play, leads to the requirement for an effective soccer-specific conditioning process to be implemented, particularly in non-starter players (Anderson et al., 2016). Therefore, soccer conditioning coaches should look to individualise different training methods following a match by considering individual players' match time exposure (e.g. starters vs non-starters) for an effective management of their load.

> *The ones who tend to do the running of the ones who don't get much of the game time so if I say travelling four or five on a day after the game with the subs in the sport.*
> Frank (PC)

The fitness coaches suggested that even though training periodisation may be a potential hindrance to physical development that providing players with additional sessions or running who are less involved in matches is important to reduce injury risk. In turn they felt that they are more readily prepared for the next match they are required to be involved within.

Is training periodisation as hindrance to long term development?

Coaches identified that while important for first team models and requirements that it may not be as important to partake in a classic periodisation model within youth soccer. Linking this with comments made regarding participating in matches under fatigue, this evidences further the notion that the development process may not always be about winning matches, more so the long-term development of the athletes. Further comments were made that a periodisation model may in fact limit the ability for technical and tactical skills to be fully worked upon. However, fitness coaches were keen to stress, when increased match play demands are placed upon developing players, considerations should be made regarding the recovery strategies that are required. For instance, one fitness coach suggested that for LTAD, the players participation in training and matches is key, therefore sometime training sessions should be modified to reduce the risk of potential injury and subsequent loss of development opportunities.

> *you got to be very careful that you want to adopt a periodized model which is now sort of like been accepted, I'm not sure it's a developmental model.*
> Alan (AD)
> *we have been on more of a sort of like a player recovery model, rather than trying to achieve adaptation through training but not because that's the philosophy of the staff if that makes sense it's the constraints that have been put on us.*
> Henry (PC)

Individual work relating to game specific movement demands and needs within a team setting

An important aspect of the coaching program at this club was to focus highly on the individual and the requirements that they required to improve upon. Time is made within the session to allow for individualised aspects to be focused upon within the academy developmental environment, rather than at first team level where it is about the team. The exact content of the individual work is depending on strengths and weaknesses of a player with everyone from the director to the fitness coach understanding the rationale for the additional content and potential removal from football specific practice.

Mainly from the game, I think that tells you a lot. What are they struggling with one v one footwork and then try to link that into the technical and tactical side.

Alan (PC)

What works well is they come over to me for even if it was eight minutes if they're technically quite efficient, what they're lacking in the speed. And that's something that I get some individual time for

Issac (PC)

I think that its completely up how important the physical part is depending on the person that you're working with.

Alan (AD)

Yeah so it's a really individual thing on their own merits. They all have their own strengths and areas of weakness. That can be in any of the corners. They will have their own fitness can be in any of the corners, they can be across the corner,

Ewan (TC)

General Dimensions, Higher and Lower order themes explored within Stage 3- Specific Thoughts on the physical development of youth soccer players

Table 3.3 General Dimensions, Higher and Lower order themes extracted within Stage 3 of Interview schedule

Lower Order Themes	Higher Order Themes	General Dimensions
Objective Data	Relative importance of physical development indicators	Physical Development
Importance of gym work		
Measures of physical development		
Modified schedules on an individual basis		
Integrated staff approach to physical development		

Physical Development

The physiological development of players is highly complex, and adaptation occurs over a long period of time. Firstly, as mentioned like any team-based sport, the coach has the largest say on both the training program and the overall development of the players. Based both

upon their past experiences and opinions the on-pitch load is ultimately decided based on what is best for them to match their needs. In light of this, the coach's role is to determine, along with support staff the micro, meso and macro cycles which potentially influence the adaptations of the players during the training weeks and months (Malone et al., 2015; Akenhead et al., 2016). Along with the planning of sessions, when it comes to delivery, different coaches have different styles of on pitch coach engagement which may elicit different physical responses. This is also replicated in match play, where the coaches will have the final say in formation and styles (Bradley et al., 2013). In addition, there are potentially, periods of time within a player's youth development where maximal development opportunities may occur. The period of time in which they go through maturational changes is often seen as a vital period for developing the player. For instance, when players of similar age, but differing maturation stages are tested for physical performance, may be indicative of performance changes (Pearson et al., 2006b). An example of this could be changes in maximal power being reported to increase by 365% between ages 7-17 (Martin et al., 2000). Muscular factors are prominent in explaining the development of maximal power.

Relative importance of physical development indicators and measures of physical development

In order to be able to accurately measure physical development within elite youth soccer players, reliable and valid physical performance test are required. These physical performance tests are usually based upon muscle strength, power and functional movement performance under standardised test conditions (Jaric et al., 2005). A number of factors should be understood before fully reporting the outcome of these tests within youth soccer players, such as changes in body composition, age, gender, duration between testing time points and maturity status of the player (Ford et al., 2011; Philippaerts et al., 2006). An objective understanding of the player can therefore be made prior to the subjective decisions based upon the technical and tactical capabilities.

> *From a physical standpoint it's the usual ones just speed, strength, stamina agility, all the things that we deem to be sports specific skills that that can then help them perform better on the pitch.*
> George (PC)

we will begin to use that to at least signpost us towards some of the areas of development and then that then gives you something to track over time.
Jordan (TC)

Objective Data

Coaches were split in terms of the importance of objective data and the level the data is used to form opinions and drive practice. It seems that technical coaches, in regard to physical data, seem to use it as evidence to reiterate their point rather than to inform and make decisions. The philosophy of the club seems to suggest that the fitness coaches also understand that football comes first and that the numbers and data surrounding are there to be used in tandem with the watchful eye of the coach. A combination of both objective and subjective measures seems key in order to prescribe and measure the development of athletes.

I think Your objective data that you can get on a player, the markers that you might want physically or technically your numbers anything else that only paints part of the picture, yet but really I don't think it's ever going to substitute for what your eyes see someone feels,
Alan (AD)
And we don't do loads of objective fitness testing, necessarily, I think, yeah well that from the game or from training with that player that's still my barometer.
Frank (PC)
I feel sometimes that we end up trying to hit the physical numbers to the detriment base or it overpowers all elements of it
Dave (TC)
For example, I know he's been working on a specific run, and then he makes it in a game, and you are happy because you almost are justifying the work that you have been working on in training.
Dave (TC)

In addition, technical coaches seemed to stress that on occasion, trying to hit specific objective numbers and markers can perhaps take away from the coaches technical and tactical focus and therefore it potentially may lose its focus. On the other hand, fitness coaches are required to provide this data to the coaches, and it can in fact evidence practices enhancing performance, therefore used in the right manner fitness coaches believe it can help aid practice.

Yeah, I like certain performance deficits, or you know, gaps in their game where they need to improve your following questions question them this nice this.
George (PC)

Importance of Gym work

There were varied opinions as to the importance of gym work for youth soccer development, but the overriding outcome was that it is an extremely important part. This mainly was evident as the coaches had made the link between time spent in the gym and time spent out on the training pitches and game involvement. Instead of the coaches focusing on the specifics around the importance of gym work, it was mainly evident that they were concerned that participating in gym-based work whether that was strength training or injury prevention based exercises, was that it allowed the coaches for more time to work with them to enhance their technical tactical capabilities. The coaches understand that demands of the modern game are far greater than previous times and therefore the physical preparation should reflect this.

I think it's massive, I was it was a real blind spot for me my until four years ago really. He showed me these stills of like their movements and think you know that stuff that you take. I could not believe some of the stuff I see is like the difference in like their flexibility and there. If you like there was one where it's like, on a bench or like I said reach tests often got the differences unbelievable.
Dave (TC)
because you want players that can cope with the demands of the modern game, and the modern games but the physical.
Jordan (TC)

Integrated staff approach to physical development

To allow for the best opportunity for players to achieve optimal levels of physical development, it requires the technical coaches to buy into the physical aspect of the process. Within interviews it was evident that both the coaches and fitness coaches understood the importance of physical development and all parties wanted to develop it as best as possible.

We always, always try to do within the football. Yeah, always. Having said that, I still thought there was a place of time and a place for separating the physical from the football sometimes.

Callum (TC)

I'd say. Up until now, probably has been more integrated. Yeah, but I think because of that stuff being said there about the smaller groups with the area size and so again the physical numbers without the football

Dave (TC)

In terms of the football side of it is, it's an integrated approach where we use games on certain days we use certain drills on certain days at certain times on certain days to to try the the metrics that we're looking for.

Henry (PC)

Modified schedules on an individual basis

Modifying a player's schedule was largely responded to in relation to the phase of development commonly known as maturation. Within this phase, various physical changes take place within the players physique which cause alterations in their capabilities. Considerations should be made as to their levels of participation in full time programs when they are within the peak height velocity phase of maturation. Coaches were keen to stress that they would rather modify a program to allow for players participation in as many sessions as possible, rather than participating in all available sessions and in turn becoming injured and missing a large proportion of development opportunities. The players may not always understand their removal from full training to part training and therefore the coaches understood that it is part of their job to fully explain the rationale as to why they are involved in only part of the training. In addition, the academy director suggested that perhaps one strategy should be to involve them in full training, become injured and learn themselves as to why they should have been involved on a modified schedule.

One strategy around it which might be kinder for the boys realise they can't quite get over there and actually better to be riddled with injuries, but at least they know.

Alan (AD)

I don't think that we should ever put them at risk or harm but rather than avoiding. For instance, I would always encourage. If they were to try not middle day that they do come out they are involved

but their loading is completely restricted.
Ewan (TC)

Coaches were keen to stress that being involved in some training and matches is far more beneficial than none at all.

for them to miss out the occasional training session to try and minimise the risk of an overuse growth injury, which can then put play off for three, three months. I think is a far more sort of sensible and reasonable thing, and would improve their chances of becoming a player i think you know once you start getting these bigger injuries,
Frank (PC)

Limitations

Despite this being the first study of its nature to investigate the opinions of key stakeholders within such environment, it is not without limitations. The approach used (one club) which limits the generalisability of the findings as it is only the opinions of one environment, however we believe the key messages in can be applied to any sport performance environment. A further understanding in the future of other clubs′ ideas around the relative importance would however allow for a cross level of cross-comparison of physical development in youth soccer to evolve in more detail. Another potential limitation is due to the relationship between the researcher and the coaches, an influence in relations to the discussions and answers within the interviews may have been observed, although all measures prior with employed to ensure open and honest discussions were adhered to. It should be noted however though, that the coaches interviewed in the study did however have a vast experience of training in top leagues of different countries, so their opinion is most likely representative of other elite coaches in soccer.

Conclusion

To summarise, this study used semi-structured interviews with eleven key stakeholders from one professional club′s academy to understand the relative importance of physical development to be observed. This allowed us to confirm and provide new insights into the

different approaches used for physical development within elite youth soccer, with chapter 5 of this thesis then attempting to understand how physical development is implemented in this club from a quantitative standpoint. It was evident from the interviews that both practitioners and future research in this area should focus on the evaluation of the physical development strategies which are employed in elite youth soccer as coaches deemed this a key and pivotal part within the over success of a youth player. In addition, five key themes emerged via thematic analysis relating to the research question (see figure 4.2) and future suggestions for research. There was a high level of agreement on factors influencing and the relative importance of such factors to the successful progression of a youth soccer player to the first team. Overall, as previously mentioned, it was evident that coaches, both technical and physical, believed that physical development within elite youth soccer is crucial part of the holistic training programs that are employed within the academy in question.

Given the expertise of the coaches that were interviewed, soccer practitioners could consider the findings useful as it provides an understanding of the importance of specific methods of physical development integration in a holistic training program. Moreover, it should be noted that a key theme which arose from this study was that having a clear structure in place within the club, allowing for all staff and players to have a comprehensive understanding of what the main goals of the development process, is key for the overall success. For example, if a staff member leaves, a new member could come in and be embedded in a process that would see the academy′s ideas to be continued to be relayed in practice. Therefore, evidence and coaches′ beliefs corroborate that physical development, and having an integrated staff approach to do so is of upmost importance. Naturally, the main objective of the academy process is to get a youth player into the first team, and that strategies, including physical ones should be implemented to get a favourable outcome. It seems therefore that the stakeholders within this club believed that any method to enhance the possibility of a player succeeding in the academy is one which is important and should be fully evaluated for its potential effectiveness.

CHAPTER FOUR

THE ASSOCIATION BETWEEN TRAINING LOAD AND PHYSICAL DEVELOPMENT IN PROFESSIONAL MALE YOUTH SOCCER PLAYERS: A SYSTEMATIC REVIEW.

Introduction

Within professional male youth soccer, the training process is deemed central for a successful transition of players through playing pathways and development programmes (Bergeron et al., 2015). Coaches within chapter 3 described physical training as a key aspect of a holistic training program. For players to advance successfully though, they must be prepared for the next level of competition from not only a physical perspective, but also mentally, technically and socially (Ford et al., 2011). Soccer coaches and support practitioners are responsible for both the design and delivery of player development programmes with the ultimate aim to produce a player worthy of a regular place within the senior team. This notion has led to significant investment across professional soccer clubs to enhance the resources available for both the recruitment and development of their youth players (Wrigley et al., 2014). Whilst player development can be impacted by internal factors, such as genetics, the structure of training programmes is within control of the practitioner to appropriately manage in order to maximise the chance of success.

It is important for practitioners working within elite youth soccer to understand how the training load which a player has been exposed to relates to the outcomes of such tests. As such, effective training strategies in soccer are implemented with the aim of increasing performance for players during competition. However, within youth soccer, as understood by the interviews in chapter 3, the outcome of competitive match play may not always be the main priority due to the developmental nature of academies. The findings of chapter 3 further demonstrate that coaches and other key stakeholders deemed physical development an

important aspect of a players programming within youth soccer academies. Therefore, it seems sensible to understand the current literature which provides insights as to the methodologies and processes which have been previously employed within youth soccer to both track and monitor training, one of which is the systematic involvement in match play. In doing so, the methodology of chapter 5 can be shaped in a way which can develop upon previous ideas to provide novel research in youth physical development.

From a physical perspective, it is common for practitioners to monitor the training load (TL) undertaken by their players in order to understand both the external load and internal response of each individual player (Impellizzeri et al., 2019). The quantification of external load is often monitored using global positioning systems (GPS) containing embedded inertial sensors to collect information of variables such as distances covered at different velocities, acceleration and deceleration efforts and estimated metabolic power (Akenhead & Nassis, 2016). The internal load is typically quantified using heart rate telemetry and subjective scales, such as the rating of perceived exertion (RPE) and wellness ratings (Akenhead & Nassis, 2016). Whilst assessment of the daily external load helps coaches understand whether the planned content matches that of the observed load, the internal load represents the important stimulus for training induced adaptation (Viru & Viru, 2000).

In order to understand the long-term effects of accumulated TL, it is important that practitioners employ soccer-specific physical performance tests to understand how each individual player is responding to the development programme. Practitioners will often incorporate multiple testing points during an annual macrocycle to determine changes across different physical qualities (Svensson & Drust, 2005). Testing protocols are typically conducted within the field due to the practical limitations of laboratory-based testing across large numbers of players. Common tests used within youth soccer include the Yo-Yo intermittent test (Krustrup et al., 2003), the 30-15 intermittent fitness test (Buchheit & Rabbani, 2014), countermovement jump (CMJ), sprint testing (10m and 30m) and repeated sprint ability (RSA) (Jaspers et al., 2017). It is important that the test used in practice are reliable, valid and sensitive to changes in fitness across longitudinal periods (Svensson & Drust, 2005).

In order to determine the effectiveness of youth soccer player development programmes, it's important that practitioners understand the associations between measures of TL and physical performance tests. Whilst this association has recently been evaluated in senior professional soccer players (Jaspers et al., 2017), there is limited information available to practitioners around which TL measures and physical tests are most suitable for youth players development. Therefore, the purpose of this systematic review was to: 1) evaluate current physical performance tests used within professional male youth soccer in relation to their sensitivity to change; 2) to understand the relationship of these tests to measures of external and internal TL.

Materials and Methods

Literature search strategy

Articles were systematically identified via five electronic databases (PubMed, Medline, SPORTDiscus, Web of Science, CINAHL and Scopus) using the search strategy presented in Table 4.1 Terms within the search strategy (search strings 1, 2, 3 and 4) were connected with the 'OR' function. Three articles were identified from additional sources known to the authors. The search was conducted on 30th April 2020, therefore any article published after this time was not included. The key terms and definition used for the systematic review process are presented in Table 4.2.

Table 4.1 Search strategy used to locate relevant research articles.

Variable	Search Terms
Search String 1 (Soccer)	Soccer OR Football
Search String 2 (Youth)	Youth OR Junior OR Young
Search String 3 (Training Load)	Soccer OR Football AND Youth OR Junior AND Load OR Stress OR Work OR Workload OR Type OR Frequency OR Volume OR Time OR Duration OR Intensit* OR Training
Search String 4 (Physical Development)	Soccer OR Football

	AND Youth OR Junior AND (Fitness OR Capacit* OR Adaptation OR Development OR Physical development OR Aerobic capacity OR Power OR Strength OR Testing OR Abilit* OR Competition OR Game OR Speed OR Repeated Sprint OR Perform*

Table 4.2 Key terms and definition used for the systematic review process.

Variable	**Definition**
Training Load	The product of volume, frequency and intensity of a given training program (Impellizzeri et al., 2014)
Physical Development	Physical development which can also be termed as 'physical training' is the systematic repetition of physical exercises, and it can be described in terms of its outcome (anatomical, physiological, biochemical, and functional adaptations) or its process. (Impellizzeri et al., 2014)
Internal Load	The internal training load represents the physiological stress imposed on the athlete in response to the training stimulus (e.g., perceptual rating of intensity, heart rate, hematological measures.) (Scott et al., 2013).
External Load	External load is defined as the work completed by the athlete, measured independently of his or her internal characteristics (Wallace et al., 2009)
Adaptation	Biomechanical adaptations take place through mechanical stresses to the various musculoskeletal tissues. Muscular adaptations are perhaps best known and the most responsive to mechanical stimuli.
Aerobic Performance	Aerobic performance is determined by both aerobic power and aerobic capacity

Aerobic Capacity	Expresses the ability to sustain exercise for a prolonged period and is synonymous with endurance.

Selection criteria

This review was conducted according to the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines (Moher et al., 2019). For the purpose of this review, articles were excluded from the initial search (title and abstract only) if (1) the participants were not male soccer players; (2) the article was not an original article in a scientific peer-reviewed scientific journal; (3) the article was not related to training load and fitness. Following this, from the remaining articles, the full texts were analysed, and articles were excluded if they did not fit the following criterion: (1) Participants were over the age of 23; (2) the participants were non-professional; (3) the article investigated other aspects of training (e.g. rehabilitation, altitude, nutrition); (4) the article did not report and training load measures; (5) the article did not report any physical development measures; (6) the article was unavailable in English.

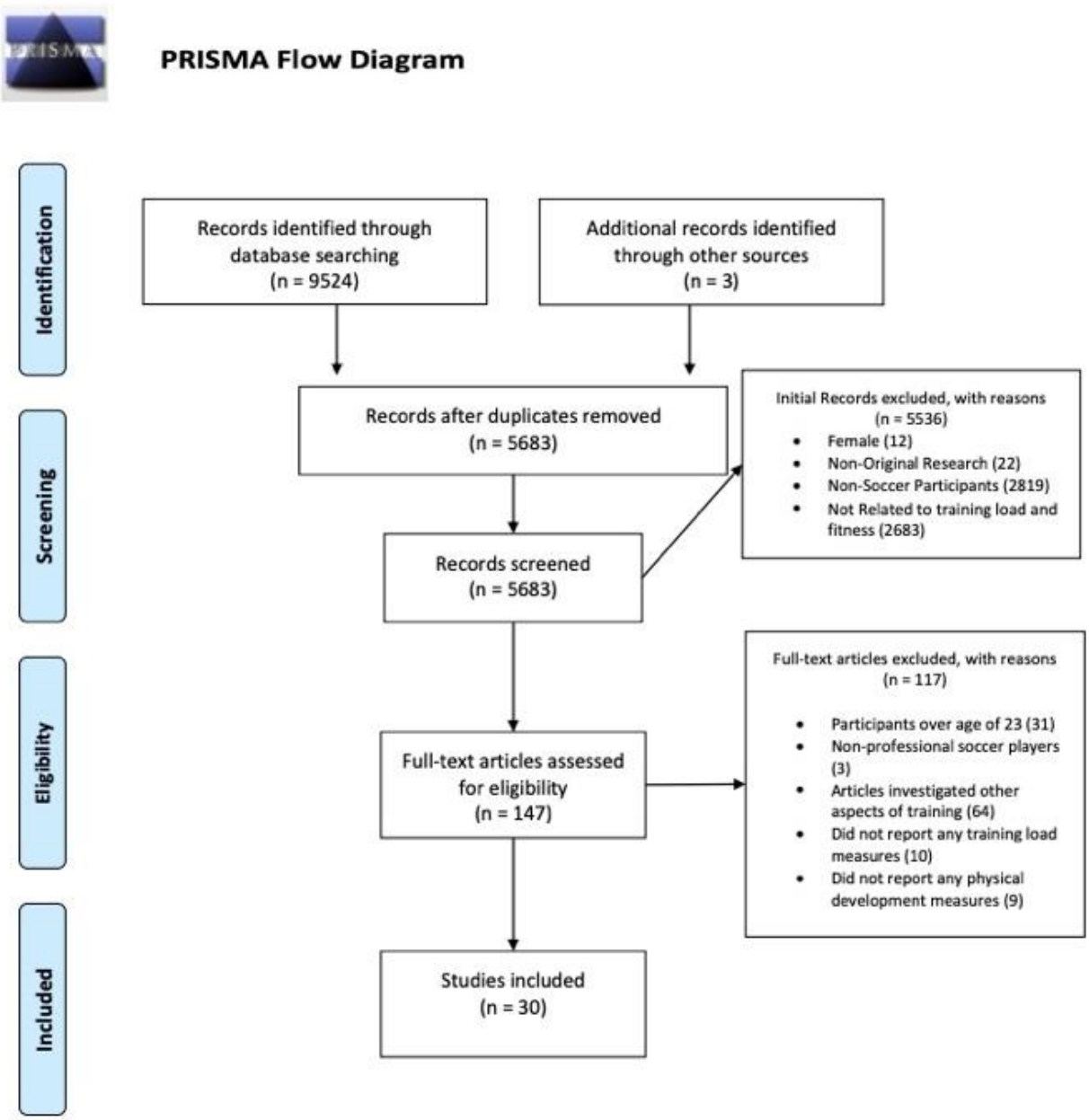


Figure 4.1 Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) flow diagram of search strategy

Methodological quality assessment

Methodological quality was assessed using a modified Downs and Black checklist (Downs & Black, 1998). The checklist has been applied previously to systematic reviews assessing cross-sectional and longitudinal studies (Fox et al., 2017; Heydenreich et al., 2017; Prince et al.,

2018). All the studies that were included were measured against the answers to ten questions (Table 3). Each item is scored as 1 = "Yes", and 0 = "No/unable to determine". The scores for each of the 10 items are summed to provide the total quality score. If the score was less than 4 then the article would be removed from the review. The quality of each included article was rated against the checklist independently by two authors (JR and JM).

Table 4.3 Questions within the modified Downs and Black checklist used to evaluate methodological quality of the articles which are included.

Question	Details
	Reporting
1	Is the hypothesis/aim/objective of the study clearly described
2	Are the main outcomes to be measured clearly described in the Introduction or Methods section?
3	Are the characteristics of the subjects included in the study clearly described
4	Are the main findings of the study clearly described
5	Does the study provide estimates of the random variability in the data for the main outcomes
6	Have actual probability values been reported for the main outcomes except where the probability value is less than 0.001
	External Validity
7	Were the subjects asked to participate in the study representative of the entire population from which they were recruited
	Internal validity-bias
8	If any of the results of the study were based on "data dredging", was this made clear?
9	Were the main outcome measures accurate (valid and reliable)?
10	Were the statistical tests used to assess the main outcomes appropriate?

Table 4.4 Results of methodological quality assessment for included articles.

Study	Downs and Black checklist question number										
	Reporting						External Validity	Internal validity-bias			
Study	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**
Abderrahman et al., (2012	1	1	1	1	1	1	0	1	1	1	9
Akubat et al., (2012)	1	1	1	1	1	1	0	1	1	1	9
Arcos et al., (2017)	1	1	1	1	1	1	0	1	1	1	9
Arrgui-Marin & Garcia Tabar (2019)	1	1	1	1	1	0	0	1	1	1	8
Buchheit et al., (2012)	1	1	1	1	1	1	0	1	1	1	9
Cetolin et al., (2018)	1	1	1	1	1	0	0	1	1	1	8
Figueiredo et al., (2019)	1	1	1	1	1	1	0	1	1	1	9
Fitzpatrick et al., (2018)	1	1	1	1	1	0	0	1	1	1	8
Francioni et al., (2016)	1	1	0	1	1	1	0	1	0	0	6
Gibson et al., (2018)	1	1	1	1	1	1	0	1	1	1	9
Gil-Rey et al., (2015)	1	1	1	1	1	1	0	1	1	1	9
Giminiani & Visca (2017)	1	1	1	1	1	1	0	1	1	1	9
Hammami et al., (2016)	1	1	1	1	1	1	0	1	0	0	7
Impellizzeri et al., (2006)	1	1	1	1	1	1	0	1	1	1	9
Jastrzebski et al., (2013)	1	1	1	1	1	1	0	1	1	1	9
Lopez-Segovia et al., (2010)	1	1	1	1	1	1	0	1	1	1	9
Los-Arcos et al., (2015)	1	1	1	1	1	0	0	1	1	1	8
Malone et al., (2014)	1	1	1	1	1	1	0	1	1	1	9
McMilliam et al., (2005)	1	1	1	1	0	0	0	1	1	1	7
Miranda et al., (2012)	1	1	1	1	1	1	0	1	1	1	9
Morris et al., (2018)	1	1	1	1	1	0	0	1	1	1	8
Noon et al., (2015)	1	1	1	1	1	1	0	1	1	1	9
Paul et al., (2018)	1	1	1	1	1	1	0	1	1	1	9
Perroni et al.,(2019)	1	1	1	1	1	1	0	1	1	0	8
Saidi et al., (2019)	1	1	1	1	1	1	0	1	1	1	9
Silva et al., (2011)	1	1	1	1	1	1	0	1	1	1	9
Silwowski et al., (2007)	1	1	0	1	0	0	0	1	0	0	4
Silwowski et al., (2011)	1	1	0	1	0	0	0	1	0	0	4
Silwowski et al., (2013)	1	1	0	1	0	0	0	1	0	0	4
Sporis & Matkovic (2014)	1	1	1	1	1	1	0	1	1	1	9
Williams et al., (2011)	1	1	1	1	1	1	0	1	1	1	9

Data extraction and analysis

When searching each database, the lead author (JR) examined the article title, abstract and keywords in the first stage of screening according to the established inclusion and exclusion criteria. The texts were examined to identify the terminologies employed in reference to the method used and for physical development in definition. The following data, where possible, were extracted from each article:

- Participants Characteristics - sample size, playing level, sex, age, stature and body mass
- Study Methodology - monitoring period, TL measures and physical test measures
- Study Results - TL and physical test measures compared and the results of statistical analyses (i.e. association statistic, interpretation, and statistical significance).

Results

Search findings and methodological quality

The electronic search yielded 9521 articles, with an additional 3 articles identified from an additional journal (Science and Medicine in Football). Following the removal of duplicates, 5683 articles remained for title and abstract screening. 5536 articles were removed based on initial study criteria (Figure 1). 147 full-text articles were screened and 117 were removed based on the second level of criteria, leaving 30 articles included in the final review. Figure 4.2 represents the yearly distribution frequency and cumulative sum of the number of publications included in the current systematic review. Ratings from the Downs and Black quality score appraisal for each article is presented in Table 4.4. Methodological quality scores ranged from 4 – 9, with no articles excluded based on these scores. Participant characteristics, physical test measures, technology used, and study duration are all presented within Table 4.5.

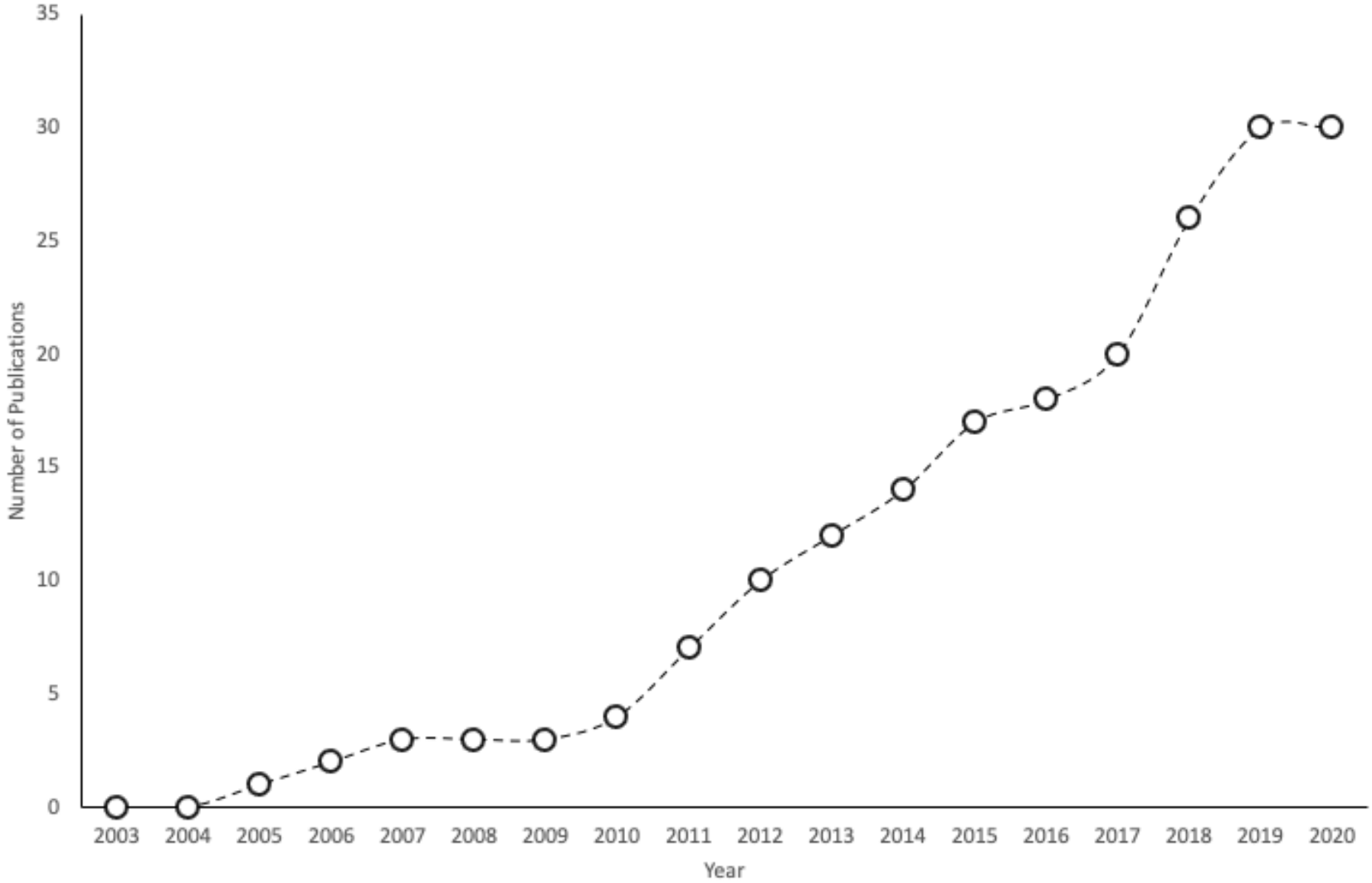


Figure 4.2 Yearly distribution frequency and cumulative sum of the number of publications included in the current systematic review addressing the association between training load and physical development in professional male youth soccer players.

Table 4.5 Demographic characteristics of participants examined in each included article.

Study	N	Age (Years)	Duration	Playing Standard	Location
Abderrahman et al., (2012)	24	14.4	8 months	Youth Academy Tunisia	Tunisia
Akubat et al., (2011)	9	17 ± 1	6 weeks	English Football League Youth alliance	UK
Arcos et al., (2017)	20	20.6 ± 1.8	32 weeks	Qatar National League	Qatar
Arcos et al., (2015)	19	20 ± 1.9	9 weeks	Spanish La Liga	Spain
Arrgui-Marin & Garcia Tabar (2019)	38	18.7 ± 1.1	18 weeks	La Liga Youth Teams	Spain
Buchheit et al., (2012)	46	15 ± 1.5	3-4 Months	Qatar National League	Qatar
Cetolin et al., (2018)	32	14.7±0.5 & 18.9±09	8 weeks	Brazilian First Youth Division	Brazil
Figueiredo et al., (2019)	16	18.7 ± 0.68	3 weeks	Brazil first division team	Brazil
fitzpatrick et al., 2018	14	17 ± 0.5	6 weeks	U18s Premier League	UK
Francioni et al., (2016)	33	14-15 Year olds	Full season	Italian Premier League	Italy

Gibson et al., (2018)	30	14 ± 0.4	5 days	Professional Youth academy	UK
Gil-Rey et al., (2015)	14 Non-Elite/14 Elite	17.6 ± 0.6	9 Weeks	Spanish third division	Spain
Giminiani & Visca (2017)	19	13.3 ± 0.1	2 Year Analysis	Italian First Division Youth	Italy
Hammami et al., (2016)	20	14.4 ± 0.3	2 Year Analysis	national selection of Tunisia	Tunisia
Impellizzeri et al., (2006)	29	17 ± 0.8	12 weeks	Italian Championship	Italy
Jastrzebski et al., (2013)	19	16 ± 0.3	Season Long	Poland	Poland
Lopez-Segovia et al., (2010)	19	18.4±0.6	16 weeks	U19s Spanish first division	Spain
Malone et al., (2014)	9	16.4 ± 0.5	1 week	U18s Premier League	UK
McMilliam et al., (2005)	9	18.3 ± 0.3	Full season	Scottish Youth Premier League	Scotland
Miranda et al., (2012)	13	17.0 ± 0.7	10 weeks	French Youth Premier League	France
Morris et al., (2018)	112	U12 – U18	Season Long	English Football League Academies	UK

Noon et al., 2015	14	17 ± 1	Season Long	Category 2 Academy	UK
Paul et al., 2018	19	16 ± 0.8	5 Days	Qatar National League	Qatar
Perroni et al., (2019)	35	14 ± 0	8 weeks	Italian Youth League	Italy
Saidi et al., (2019)	13	20.4 ± 0.4	6 weeks	Tunisia Youth league	Tunisia
Silva et al., 2011	18	N/A	Season Long	Tier 2 Portugal	Portugal
Silwowski et al., (2007)	22	14-15 Year olds	8 weeks	Polish Youth League	Poland
Silwowski et al., (2011)	15	14-15 Year olds	Full season	Polish Youth League	Poland
Silwowski et al., (2013)	Not mentioned in article	14-15 Year olds	Full season	Polish Youth League	Poland
Sporis & Matkovic (2014)	64	N/A	Season Long	First Croatian Junior League	Croatia
Williams et al., (2011)	200	5 age groups	3 Year analysis	English Football League Academy	UK

Physical tests sensitive to change in performance

The first sections of the results will present information that is relevant to the first aim of the manuscript. More specifically data will be presented that analyses the change in specific physical tests over time.

Physical performance tests to detect change in aerobic fitness

Twelve studies (Noon et al., 2015; Perroni et al., 2019; Abderrahman et al., 2012; Gibson et al., 2018 Silwowski et al. 2011; Akubat et al., 2011; McMilliam et al., 2015; Miranda et al., 2012; Silwowski et al., 2007; Silwowski et al., 2013; Giminiani & Visca, 2017; Jastrzebski et al., 2013) used physical performance tests to detect changes in aerobic fitness across various testing points. Four of these studies used YoYo based tests to detect changes in physical performance (Noon et al., 2015; Perroni et al., 2019; Abderrahman et al., 2012; Gibson et al., 2018). Noon et al., (2015) and Perroni et al., (2019) used the YoYo Intermittent Recovery Test Level 1 (YoYo IRTL1) with both finding large increases in test scores from the start of pre-season to the end of the in-season period (see table 6). In addition, Abderrahman et al., (2012) used the YoYo IRTL 2 and found VO_{2max} scores significantly increased from testing point 1 (October; 47.9 ± 1.9) to 2 (May; 55.7 ± 2.2). Gibson et al., (2018) found differences in YoYo IE2 between HPG & LPG were trivial across the testing points.

Eight studies used an incremental test derivative performed on a treadmill (Silwowski et al. 2011; Akubat et al., 2011; McMilliam et al., 2015; Miranda et al., 2012; Silwowski et al., 2007; Silwowski et al., 2013; Giminiani & Visca, 2017; Jastrzebski et al., 2013). Akubat et al., (2011) found no significant changes in fitness across the six weeks (preseason phase): vLT ($p = 0.54$), vOBLA ($p = 0.16$), LTHR ($p = 0.51$) and OBLAHR ($p = 0.63$) with Silwowski et al., (2011) showing the most favourable changes (see table 6) in terms of exercise adaptation of the participants were noted after the basic preparatory period. Miranda et al., (2012) did show that running intensity at lactate minimum and the anaerobic parameters of the running test increased over the season. Likewise, McMilliam et al., (2015) reported increases in mean running velocity at velocity at lactate threshold (V-Lac) and velocity at 4mmol (V4mM) from the start of pre-

season training to October. Two studies (Silwowski et al., 2007; 2013) reported similar findings with both studies finding significant improvements across training in the respective training periods. Giminiani & Visca, (2017) found a significant difference on the VO_{2max} +5.72% , HR -1.70% using an Aerobic Endurance test of VO_{2max}, although considerations upon growth and maturation should be added as over such time period this would likely have had an effect although not analysed in the study. Jastrzebski et al., (2013) found significant changes in VO_{2max} from the start of pre-season to mid-season. (prior to pre-season; 58.5 ± 8.09, middle of season; 63.6 ± 4.16, and end of season; 59.4 ± 4.77 $ml \cdot kg \cdot min^{-1}$)

Physical performance tests to detect change in Lower Body Power Performance

Two studies analysed the effect of a microcycle on CMJ performance (Gibson et al., 2018; Malone et al., 2015), both revealing no significant changes in CMJ. This may suggest an insensitivity of the CMJ to detect changes or perhaps the length of assessment was too short to observe a significant change. Several other studies also found no significant differences in CMJ jump height performance from pre- to post-testing periods (Paul et al., 2018; Los-Arcos et al., 2015). In contrast, six studies (Williams et al., 2012; Silva et al., 2011; Abderrahman et al., 2012; Perroni et al., 2019; Lopez- Segovia et al., 2011; Sports and Matovic 2014) found a general significant increase from the start to the end of the season in CMJ height. More specifically, Abderrahman et al., 2012 found CMJ increases were significant from testing time point 1 to 2 (pre season to start of in season), with Perroni et al., (2019) also finding significant increases in CMJ performance across pre-season. Although Lopez-Segovia et al., (2011) analysed two squads with slightly different training programmes, both squads significantly improved their CMJ jump performance after a 16-week training block. Sports and Matovic (2014) found that starting players showed a significant improvement in maximal CMJ jump height across a full season of soccer training and competitive matches. Finally, Francioni et al., (2016) found significant variations across six testing sessions (T0 = start of preseason, T1 = end of preseason, through to T5 = end of competitive season) (T1 = 23.6 ± 4.3, T4 25.4 ± 4.8), although with no clear consistent increase in CMJ across the season.

In relation to strength-based measures only two studies analysed the physical changes (Morris et al., 2018; Silva et al., 2011) Morris et al., found significant differences in isometric mid-thigh pull (IMTP) across the season and there were increments in the H/ Q ratio and Agility from E1 (start of pre season) and E2 (end of pre season) to E3 (mid season) and E4 (march) (p, 0.05–0.01) (Silva et al., 2011).

Physical performance tests to detect change in Sprint, agility and anaerobic capacity performance

The effects of long-term training and changes in sprint and agility capabilities were assessed in eight studies (Hammami et al., 2017; Williams et al., 2012; Abderrahman et al., 2012; Miranda et al., 2012; Paul et al., 2018; Noon et al., 2015; Los-Arcos et al., 2015; Morris et al, 2018). Both Paul et al., 2018 and Noon et al., (2015) found no significant differences in change of direction performance across the respective time periods. However, in contrast, over a season-long period using the same arrowhead agility test, Morris et al., 2018 did find significant differences in change of direction ability although it should be noted that the analysis was conducted in matched on maturity status with control groups. Two studies analysed sprint performances across the pre season phase (Hammami et al., 2017; Williams et al., 2012) with findings suggesting there were general moderate decreases in sprint time (30m) over the course of the 8-week pre season phase (p=0.002). (Morris et al., 2018) also found significant differences in 10m (2.03 ± 0.16 to 2.01 ± 0.17) and 30m (4.96 ± 0.27 to 4.90 ± 0.30) sprint scores. In addition, both Abderrahman et al., (2012) and Los-Arcos et al., (2015) observed significant negative correlations between individual 30m sprint times between test point 1 (start of pre-season) and 2 (end of pre-season).

Jastrzebski et al. (2013) found Wingate test levels of relative peak power (11.2 ± 0.8 W/kg -1, pre-season; 12.0 ± 0.8 W/kg -1, end of season) although this was assessed through cycle ergometry perhaps suggesting a lack of specificity (running vs cycling) which may impact the sensitivity to detect change.

Associations between external training load and changes in physical test measures.

External training load and changes in aerobic performance

Six studies (Fitzpatrick et al. 2018; Gisbon et al. 2018; Impellezerri et al. 2006; Gil-Rey et al. 2015; Paul et al. 2018; Buchheit et al. 2012) examined the correlation between total exposure (training and games) and changes in aerobic performance although the association between other external load variables and changes in aerobic performance was only assessed in one study (Fitzpatrick et al. 2018). Correlations and linear regression were analysed across a six-week time period for total distance, distance covered above 17 km/h and distance covered above 21 km/h along with individualised threshold measurement for maximal aerobic speed (MAS) and maximal sprint speed (MSS). They revealed an improvement in mean MAS score of 0.11 km/h, which demonstrated a very large linear relationship with time above MAS during training and match play (r = 0.77).

The correlation between exposure to increased total distance in both training and match play was assessed against the YoYo Intermittent Endurance Test (YoYo IE2) and a VO_{2max} test in two studies respectively (Gisbon et al. 2018; Impellezerri et al. 2006). Gibson et al., 2018 found that differences in YoYo IE2 between players involved in high minutes of available match playing time >250 (HPG) and low minutes of available match playing time (LPG) <250 were trivial (HPG: 1640 ± 339 m; LPG: 1596 ± 316 m). Impellezerri et al. (2006) found significant correlations between VO_{2max} and both the total distance covered during the matches and the time spent in high-intensity activities (mean r=0.55 and r=0.45, respectively).

Correlations between training volume and accumulative respiratory and muscular leg load were measured in one study (Gil-Rey et al., 2015). Large and positive correlations were (r = 0.71; CI (95%): 0.42 to 0.87 and r = 0.69; CI (95%): 0.40 to 0.85, respectively) found with changes in aerobic fitness assessed via Université de Montreal endurance test - time to exhausion. In addition, Paul et al., (2018) found a 4-week period of intensified training improved endurance (30-15 IFT test) by 8.2% following high intensity training compared to a group with additional small-sided games (SSG), demonstrating that increased specificity of training may correlate with improvements in aerobic performance. Buchheit et al. (2012)

found that submaximal mean HR during last 30s of 5′-5′ exercise period (% max) termed HRex, were moderately-to-largely correlated (r= 0.39) with changes in most of the performance variables (HRR, sprints, and repeated sprint performance) over the entire season.

External training load and changes in neuromuscular performance

Correlations between total exposure and neuromuscular variables were analysed in three studies; Gil-Rey et al., (2015); Noon et al., (2015); Malone et al., (2014). One study used GPS to provide correlations between indicators of external training load; duration, total distance, average speed, and high-speed distance with outcomes from physical testing protocols (Malone et al. 2014). No correlations (p = 0.23) were found between absolute changes in TL & jump height across a one-week micro cycle. In both Gil-Rey et al., (2015) & Noon et al., (2015) small and trivial correlations were found between total exposure and neuromuscular variables. Gil-Rey et al., 2015 found increases in jump height were indicative of increased training and match exposure while Noon et al., (2015) found increased training exposure (training duration) was associated with small decreases in CMJ ($P < 0.05$; $P = 0.18$). Sports and Matovic (2014) found that starting players showed a significant improvement in 5, 20, 30m sprint time across a full season of soccer training and competitive matches.

Internal training load measures and changes in aerobic and anaerobic performance.

Correlations between individualised training impulse (iTRIMP) and changes in aerobic performance were measured in two studies (Figueiredo et al., 2019; Akubat et al., 2011). Akubat et al., (2011) used a incremental treadmill protocol to analyse the training and match load across a period of six weeks which was quantified by various ratings of perceived exertion (RPE; session RPE, Banister's TRIMP, Team TRIMP and individualised TRIMP. A significantly increased running speed at velocity at lactate threshold (vLT) was correlated to the mean weekly iTRIMP ($r = 0.67$; $p = 0.04$; CI: 0.01 to 0.92; ES = large). Figueiredo et al., (2019) also collected session RPE along with HR data during the pre-season period and used this data to calculate the training intensity distribution into 3 zones (low, moderate and high). Players who consistently were in the 'high zone' had the greatest change in YoYo IRL1.

In two studies (Los-Arcos et al. 2007; Saidi et al. 2019), RPE based variable variables, in combination with training duration were used to correlate total session rating of perceived exertion with changes in aerobic performance. Los-Arcos et al., (2017) found that total duration demonstrated a large negative correlation (r = -0.53) with the change in the aerobic fitness performance running velocity associated with a [La]b of 3 mmol·l-1 (V3), blood lactate accumulation at 12 km·h-1 (Lac12) and blood lactate accumulation at 13 km·h-1 (Lac13). Furthermore, sRPEres-TL and sRPEmus-TL demonstrated a large negative correlation (r=-0.56) with the change in Lac13, whereas the changes in 15 m sprint time correlated with sRPEres-derived measures (r = -0.53). When comparing YYIR1 test performance and RPE measures, Saidi et al., (2019) found no significant relationship. As there is a large body of research which demonstrates that the YYIR1 is sensitive to change (Bradley et al., 2018), perhaps this suggests the lack of rigour that is behind using RPE as a training load measure.

Internal training load measures and changes in neuromuscular performance.

Only one study analysed the effects of internal training load with changes in neuromuscular performance (Los-Arcos et al., 2015). RPEmus and associated TL volume was negatively correlated ($p < 0.05$) with changes in physical attributes (CMJ, 5 and 15m sprint performance) after a 9-week (5 weeks preseason, 4 weeks in season) period.

Table 4.6 Associations between load measures and changes in fitness.

Study	Training Load measures	Fitness Measures	Time points in season at which physical tests were administered	Associations between training load and fitness changes	Fitness Change Outcome
Akubat et al., (2012)	s-RPE, Banister's TRIMP, Team TRIMP and individualised TRIMP (iTRIMP)	Velocity at 2mmol, Heart rate at 2mmol, Velocity at 4mmol, Heart rate at 4mmol	In-Season Period Specific information unavailable from article	No correlations observed	No change in fitness observed
Buchheit et al., (2010)	N/A	HRex, Vam-Eval, HRR	In-Season Period Specific information unavailable from article	N/A	Within-player decrease in HRex submaximal HRex, HRR and Ln rMSSD at the start of the season were moderately-to-largely correlated with changes in most of the performance variables over the entire season, moderate relationships were found between individual changes in HRR and sprint and repeated-sprint performance
Di Giminiani & Visca (2017)	N/A	Explosive strength (Squat Jump & CMJ) Pre match augmentation (CMJ-SJ) 15 (SSP15) & 30m (SSP30) Sprints Aerobic Endurance via test of leger V02max	Beginning of Preparation period (preseason) of the 1st (T1), 2nd (T2) and 3rd (T3) year.	N/A	A significant main effect on the VO2Max (+5.72%; F(2.49) = 3.822; p = 0.029; ES = 1.00), HR (-1.70%; F(2.54) = 3.472; p = 0.038; ES = 0.97), SJ (+10.26%; F(2.54) = 15.254; p = 0.0001; ES = 1.53), CMJ (+7.36; F(2.54) = 8.270; p = 0.001; ES = 1.33), SSP15 (-3.50%; F(2.44) = 12.760; p = 0.0001; ES = 1.53), and SSP30 (-4.44%; F(2.44) = 5.797; p = 0.006; ES = 1.16) was observed in the two soccer seasons. Notation on effects of growth and maturation effect were mentioned
Figueiredo et al., (2019)	sRPE-TL and HR-based methods (Edward's-TL)	YoYo IR level 1	Start of Pre-Season (T1) & 3 weeks later (T2)	Negative correlations were observed between weekly mean sRPE-TL (r=-0.69), Edward's TL (r=-0.50) and change in YoYo IR1.	Yo Yo scores significantly improved from T1 to T2. (t = 5 22.6; ES 5 0.83; p, 0.05).

Fitzpatrick et al., (2018)	Total distance, accel & decel distance >2m/s2, , distance and time > 17 km/h, distance and time >21 km/h, distance and time >MAS (individualised zones), distance covered and time >anaerboic speed reserve (ASR), heart rate exertion, s-RPE	Maximal sprint speed (MSS), maximal aerobic speed (MAS)	6-week in season period of the competition phase (August to September)	A very large linear relationship was found between t>MAS and changes in MAS (r = 0.77 [90% CI 0.48 to 0.91], R2 = 0.59) Also, large relationships were found between t>30ASR (r = 0.62 [90% CI 0.22 to 0.84], R2 = 0.38), m>MAS (r = 0.50 [90% CI 0.06 to 0.78], R 2 = 0.25) and changes in MAS. Relationships between all other mean weekly arbitrary and individualised training load measures and changes in fitness parameters were found to be unclear	Mean change in MAS over training period was 0.11 ± 0.12 km.h-1 (ES: 0.15, possibly trivial, 31/69/0) and the mean change for MSS was 0.27 ± 0.20 km.h-1 (ES: 0.16, possibly trivial, 26/74/0).
Francioni et al., (2018)	Total sessions and session duration	CMJ with and without arm swing 15m sprint	Regular intervals of two months (6 times in total) across a full season T0: August (before the start of the season); T1: October; T2: December; T3: February; T4: April; T5: June (end of season)	non-linear trend of increases along the season in relation to the amount of training sessions performed.	There were significant variations across the six testing sessions with no linear trend
Gibson et al., (2018)	Total Distance Low Speed Running <13kmh High Speed Running >13kmh	YoYo IE2 CMJ 15m Sprint	International tournament of 5 consecutive match days (testing was on day 1 and 5 respectively)	N/A	Differences in YoYo IE2 between HPG & LPG were trivial Differences in time to complete a 15m sprint between groups were small and non-significant No significant differences for changes of lower body power
Gil-Rey et al., (2015)	Respiratory RPE (RPEres), Muscular RPE (RPEmus), total duration	CMJ CMJ arm swing 5 and 15 m sprints Université de Montreal endurance test - time to exhausion (aerobic fitness)	In-season T1 (January) & T2 9 weeks later (March)	Can't determine - performed correlation analysis with both professional and non-professional players as a single data set (i.e. didn't differentiate between the two groups)	Small effect size (0.32) improvement in Montreal aerobic test time to exhaustion, no other fitness changes noted (all trivial)
Hammami et al., (2013)	N/A	Anthropometric measurements, aerobic (Yo-Yo Intermittent Recovery test level 1) and anaerobic (counter-movement-jump (CMJ), squat-jump (SqJ), five-jump-test (5JT), and speed (T5m, 10 m, 30 m	In-season T1 (October) & T2 8 months later (May)	N/A	Significant improvements for following tests from T1 to T2 for soccer players (*significant at P 5 0.05.) :CMJ 31.2 ± 4.1 to 34.5 ± 4.4 SQJ 29.1 ± 3.6 to 32.3 ± 3.7 T10M 2.0 ± 0.1 to 1.9 ± 0.1 T30M 4.6 ± 0.2 to 4.5 ± 0.2 VO2MAX 47.9 ± 1.9 to 55.7 ± 2.2

Hammami et al., (2017)	N/A	Squat Jump CMJ Running speed test over 30m YoYo IRT1 RPE	The soccer players and control subjects were evaluated at five different time points: - First test, (T0) baseline at the start of the preparatory period in October 2008. - Second test, (T1) in February 2009 in the middle of the first season. - Third test, (T2) in May 2009, the end period of the first competitive season. - Fourth test, (T3) in November 2009. - Fifth test, (T4) in the end of May 2010, the end period of the second competitive season.	N/A	The 30m-sprint performances were statistically significant (p = -0.07) for soccer players during the period T2-T3 (-0.17s) and the final period compared with control subjects.
Impellizzeri et al., (2006)	s-RPE and heart rate (< 80%, 80–85%, 85–90%, 90–95%, and > 95% HRmax)	VO2max, HRmax, VO2 at lactate threshold, % of VO2max, velocity at lactate threshold, running economy at lactate threshold, Ekblom's test (time)	Both Pre-season and In-season. T1 (July), T2, 4 weeks later (August) and T3, 8 weeks later (October).	N/A	Ekbloms test significantly improved from baseline-post preseason and also pre-season to in-season. 723 ± 47 > 629 ± 36 > 609 ± 33 Significant improvement in VO2max 3.960 ± 0.383 to 4.200 ± 0.417 to 4.203 ± 0.437 and velocity at Tlac 11.3 ± 0.7 to 11.9 ± 0.7 to 12.4 ± 0.5†
Jastrzebski et al., (2013)	Exposure Time	V02 max Wingate Test Sprint Test Shuttle run of 150m	Both Pre-season and In-season T1 (Start of Preseason), T2 (Middle of season) & T3 (end of season)	N/A	The relative peak power at the end of the season (11.96 ± 0.75 Wkg21) was significantly higher (p 0.000) than before the preparation period (11.24 ± 0.78 W$kg21). A significant positive improvement in the 150-m shuttle run time was also observed at the end of the season.
Los Arcos et al., (2015)	RPE, RPEres, RPEmus, total duration	CMJ, CMJ-arm swing, CMJ-dominant leg, CMJ-non dominant leg, 5m sprint, 15m sprint, velocity at 3mmol, lactate concentration at 12 km/h, lactate concentration at 13 km/h	Start of Pre-Season (T1) and 9 weeks later at start of In season (T2)	Significant negative correlations found between RPEmus and CMJ-dominant (-0.57), CMJ-non dominant and lacate at 13 km/h (-0.7); Total duration significant negative correlations with CMJ-arm swing, 5m and 15m sprint tests	Significant improvement in 5m and 15m sprint scores (p = -0.07) no difference in other tests pre-post
Los Arcos et al., (2017)	sRPEres-TL & SRPEmus-TL	CMJ CMJ with Arm Swing 5 & 15m Sprint Aerobic fitness test (4x3min runs)	Start of Pre-Season (T1) and 32 weeks later at start of In season (T2)	Practice volume correlated negatively and largely with the change in the V3 Lac12 and Lac13 (values. Furthermore, sRPEres-TL and sRPEmus-TL correlated largely and negatively with the change in Lac13, whereas the changes in 15 m sprint time correlated with sRPEres-derived measures (r=-.53/ -.51)	Very likely moderate (ES=.62±.28) and possibly small (ES=.21±.22) improvements in CMJ and CMJAS performance, respectively, were found from Test 1 to Test 2, while the changes in the rest of the variables (i.e. acceleration and aerobic fitness) were trivial

Lopez-Segovia et al., (2010)	Volume of Training exposure (total number of sessions & duration)	CMJ & CMJ 20 (with and without load) Acceleration capacity (T10, 20, 30 & 10-20, 10-30, 20-30) Maximal aerobic speed (MAS)	Start of In season period (T1) and 16 weeks later coinciding with end of first half of regular season (T2).	N/A	CMJ: both groups improved, but not significantly statistically CMJ 20 both teams improved significantly (team A, p = 0.05; team B p = 0.01) For this variable, team A improved significantly at E2 (p = 0.01), whereas team B worsened. The differences between the 2 teams at E2 were significant (p = 0.01).
Malone et al., (2015)	GPS HR	CMJ	One week in season micro cycle (7 days)	no correlation between absolute changes in TL & Jump height	no significant differences were observed
McMilliam et al., (2015)	Training Diary/Log	Lactate threshold test	Start of Pre-Season (T1), October (T2), December (T3), January (T4), April (T5), and June (T5)	N/A	Mean running velocity at V-Lac (from 11.67 ± 0.29 to 12.96 ± 0.28) and V4mM (from 13.62 ± 0.25 to 14.67 ± 0.24) increased from the start of preseason training to October. No other statistical changes across the season
Miranda et al., (2013)	Foster's TRIMP	10, 20 and 50m Sprints Lactate minimum test Running anaerobic sprint test	Start of Pre-Season (T1) and 10 weeks later during an In season period (T2)	N/A	Possible increases in 30 and 50m time trial performance, running intensity at lactate minimum test and the anaerobic parameters of the running anaerobic sprint test (not statistically different)
Morris et al., (2018)	N/A	IMTP CMJ 10 & 30m Sprint times Arrowhead agility test	Start of preseason (T1) and end of in-season (T2)	N/A	Analysis was matched on maturity status with control groups For elite group alone improvements seen CMJ & Peak force for IMTP – not statistically significant
Noon et al., (2015)	Total Duration	30m sprint Arrowhead agility test YoYo IR level 1 test CMJ with arm swing	Start of Pre-season, (T1), In-season 1, 6 weeks later (T2), In season 2, 13 weeks later (T3) & In season 3, 10 weeks later (T4)	Lack of correlations between fitness and training load variables. The training durations are 'estimated' at 2 hours if they completed the session, rather than the actual training durations	30m sprint decreased ($P < 0.05$; $\eta 2P = 0.48$) post pre-season 4.31 ± 0.18 to 4.24 ± 0.22 to end of in-season YoYo test scores improved from baseline to in-season (both blocks) ($P < 0.05$; $\eta 2P = 0.93$) 2203 ± 334 to 2537 ± 235 and further improved between in-season block 1 & 2: 3150 ± 269
Paul et al., (2019)	sRPE and HR zones	30-15 test CMJ height COD test	Four weeks in season period (T1) October, (T2) November	Lack of correlation analysis to provide this information	Significantly improved 30-15 score in SSG intervention group (from 17.0 to 18.4km/h; $p<0.05$; ES = 0.57) No other fitness changes
Perroni et al., (2019)	N/A	CMJ YoYo IRTL1	Eight-week preseason training camp (T1) August, (T2) October	N/A	Significant increase for both squads for pre and post preseason testing for CMJ (25.23 to 29.40; ES 1.62) & YoYo IR1 VO2max (42.93 to 44.95; ES 0.62)

Saidi et al., (2019)	Session RPE	YoYo IRYL1 Repeated shuttle sprint ability Squat Jump CMJ	Six weeks in season period consisting of 10 matches (T1) Mid-April, (T2) late May	No significant relationship between performance in YYIR1 and training load parameters however there was a significant relationship between training load and changes in RSSA (r = -0.60; p<0.003)	General trend was physical fitness decline over the 6 week period although more specifically significant differences were found for the YYIR1 (2520m to 1640m; p<0.001; ES =0.5), RSSA (8.07s to 8.28s; p<0.01, ES = 0.6) and SJ (36.5cm to 35.5cm; p<0.046, ES – 0.7).
Silva et al., (2011)	Match minutes (duration)	5- and 30-m sprint CMJ Agility Knee Extensor & Flexor YoYo IE2	Full Season (T1) July, (T2) August, (T3) January, (T4) June.	The individual match playing time from T1 to T3 was correlated with the individual changes in 5m sprint time (r = 20.705; p , 0.01;). From T2 to T3, the IMPT was significantly correlated with KEND (r= 0.786; p , 0.05) and H/QND (r = 20.738; p , 0.05). From T3 to T4, the IMPT was correlated with KFD (r = 0.590; p , 0.05), KFND (r = 0.575; p , 0.05) and H/QND (r = 0.794; p , 0.05)	Significant improvements in CMJ and YYIE2 from T1 to T2 were observed (p , 0.05–0.01). The 30m sprint time improved from E2 to E3 (p, 0.01). The CMJ decreased from T2 to T3 and T4, and YYIE2 from T2 to T4 (p , 0.05). There were increments in the H/ Q ratio and Agility from T1 and T2 to T3 and T4 (p, 0.05–0.01).
Silwowski et al., (2011)	N/A	Incremental treadmill test	Full calendar year in duration (T1) after completion of the basic preparatory period; March, (T2) before the commencement of the shortened preparatory period; July, (T3) before the commencement of the basic preparatory period, January, (T4) after the completion of the basic preparatory period, March.	N/A	The tests showed significant differences in aerobic performance of young footballers in individual periods of the annual training cycle. The most favourable changes in terms of exercise adaptation of the participants were noted after the basic preparatory period
Silwowski et al., (2013)	Total Duration	Field based lactate threshold test	Full calendar year in duration (T1) after completion of the basic preparatory period; March, (T2) before the commencement of the shortened preparatory period; July, (T3) before the commencement of the basic preparatory period, January, (T4) after the completion of the basic preparatory period, March.	N/A	Significant improvements from test 2 to 4 in comparison to 2 and 3

Sporis et al., (2011)	Hours and days practice and match mins	5, 10, 20 & 30m Sprints CMJ Slalom Test for Agility V02 max – incremental treadmill test	In Season period of length (T1) end of pre-season, (T2) one week after end of competition period.	N/A	Starters showed small but significant differences for 21 out of 24 variables measured. The most significant findings of this study point to the fact that official games help in maintaining and improving agility parameters (6 out of 7 tests) as well as in maintaining and improving overall power performance of soccer players which includes sprinting, jumping and kicking the ball.
Williams et al., (2011)	N/A	30m sprint CMJ	At six month intervals following the start of preseason in year 1 (for 3 full years)	N/A	Increased 30m Sprint time and VCMJ as increases in age were seen

Discussion

The purpose of the present systematic review was to: 1) evaluate current physical performance tests used within professional male youth soccer in relation to their sensitivity to change; 2) to understand the relationship of these tests to measures of internal and external TL. In terms of aerobic capacity evaluation, both field-based (e.g. Yo-Yo test derivatives) and laboratory-based (e.g. treadmill incremental test) tests were sensitive to changes across both pre-season and in-season phases. CMJ testing demonstrated limited sensitivity to detect acute changes in lower body power (e.g. across a microcycle), but with some evidence of sensitivity when evaluating across a full season. In addition, 10 m and 30 m sprint performance appeared sensitive to seasonal changes, whereas agility testing demonstrated limited sensitivity. In terms of the relationship between physical tests and TL measures, associations were found across tests with both external TL (total distance, high speed distance, accumulated duration) and internal TL (RPE, TRIMP) measures.

It is important that practitioners include a series of testing battery points during an annual macrocycle to determine changes within individual players across different physical qualities (Svensson & Drust, 2005). The present review revealed that the majority of physical tests were sensitive to change across the pre-season phase. Typically, the pre-season phase is designed to rebuild the fitness of players following the off-season phase (Bompa & Haff, 2009) . The TL during the pre-season phase is higher than that observed during the in-season (Jeong et al., 2011). Therefore, it would seem logical that the phase with the highest TL (i.e. pre-season) would also demonstrate the most sensitivity in terms of physical test score changes. Changes in physical testing qualities were also observed from the start of pre-season to the end of the competitive season (e.g. Hammami et al., 2013; Morris et al., 2018). These observed improvements are crucial for the physical development of players to successfully prepare them for the next level of competition within the development pathway (Ford et al., 2011). Of all the physical tests evaluated, it appeared that assessment of agility provided mixed results in terms of sensitivity to change. This may be due to the lower reliability and validity of such tests, which could be attributed to the complexity of the tests that incorporate both physical and perceptual aspects of speed (Altmann et al., 2019). Caution should also be

made when using physical tests to detect acute changes in fitness, such as a weekly training microcycle, as this showed lower sensitivity compared to when assessing over a longitudinal period (Malone et al., 2015; Paul et al., 2019).

Of the articles that used physical performance tests to detect change in fitness (n=12), most (n=7) used incremental treadmill tests as a stimulus to challenge the physiological systems of the players. The findings of these studies (Silwowski et al. 2011; McMilliam et al., 2015; Miranda et al., 2012; Silwowski et al., 2007; Silwowski et al., 2013; Giminiani & Visca, 2017; Akubat et al., 2011) generally demonstrate that this modality of testing, and the equipment used to collect testing data, provides outcome measures that seem sensitive to detect changes in performance. Although the seven studies observed significant differences in physical fitness, it should also be noted that the studies measured slightly different outcome variables as "proxy" markers of fitness. Five of the studies used lactate-related variables; for example, velocity at lactate threshold and velocity at 4mmol, (Miranda et al., 2012; Silwowski et al., 2007; 2013; McMilliam et al., 2015; Akubat et al., 2011). Three (Giminiani & Visca, 2017; Jastrzebski et al., 2013; Silwowski et al., 2011) used $\dot{V}O_{2max}$ as the variable to detect change, which also seemed sensitive. Four other studies (Silva et al. 2011; Saidi et al. 2019; Perroni et al. 2019; Noon et al. 2015) in the review which used physical performance tests to detect changes in aerobic fitness across various testing points, utilized field-based tests based on the YoYo shuttle running concept. Each study found significant positive changes in fitness. In addition, one study (Fitzpatrick et al., 2018) used a MAS based test to detect change in physical performance, with findings suggesting increased time spent above individualised MAS threshold correlated with improvements in test performance. These outcomes also seem to be in keeping with previous research that has illustrated that these performance tests are both valid and reliable in detecting changes in aerobic capacity (Schmitz et al., 2018). This demonstrates that field-based tests such as the forementioned show good utility and may be used in youth soccer training programs. In summary, the findings of this review suggest that the beforementioned laboratory and field-based tests may be used in applied practice to detect changes in fitness that are related to aerobic fitness.

In terms of the quantification of TL, it is now commonplace within professional male youth soccer, with practitioners routinely collecting both external and internal TL information on a daily basis (Akenhead & Nassis, 2016). The present review revealed that common GPS-derived measures of external TL (e.g. total distance, high speed distance) were associated with positive changes in fitness. Despite the plethora of GPS variables available to quantify external TL currently, the evidence around their association to changes in fitness in professional male youth soccer players was found lacking. Indeed, the beforementioned more 'traditional' external TL variables and their association with changes in fitness has also been recently observed in senior professional players (Jaspers et al., 2017). In terms of internal TL variables, both RPE-based and heart rate TRIMP-based measures demonstrated the strongest association to changes in fitness. It would appear that both measures were associated with improvements in fitness across both the pre-season (Figueiredo et al., 2019) and in-season (Los Arcos et al., 2015, 2017) phases. Both RPEres and RPEmus were found to be associated with changes in fitness (Los Arcos et al., 2017), which could be an interesting future direction for practitioners rather than using the standard RPE approach. Interestingly, there appeared to be more studies revealing associations with external TL variables compared to internal TL variables. One reason may be due to practitioners preferring external TL data collection across both training and matches within soccer (Akenhead & Nassis, 2016). In addition, practical issues such as erroneous heart rate data (e.g. due to shocks/contacts and ill-fitting belts) can limit the collection of reliable internal TL data on a daily basis (Lacome et al., 2018).

Positive relationships between external training load/total exposure (training and games) and changes in aerobic performance were observed in six studies (Fitzpatrick et al., 2018; Gibson et al., 2018; Impellezerri et al. 2006; Paul et al., 2018; Buchheit et al. 2012; Gil-Rey et al., 2015). Impellezerri et al. (2006) found large and positive associations between VO_{2max} and increased training volume, with Gil-Rey et al., (2015) also finding increased exposure to training, RPEres, RPEmusc were positively and largely correlated (r = 0.67 – 0.71) with increased performance on the Universitie de Motreal endurance test. Some considerations should be observed when using training exposure as a sole variable to quantify the total load of the players as it does not quantify the intensity of training sessions or games. Using only

training exposure to quantify external training load also limits the ability to detect individual differences between players that may exist in the response to training. Two studies within the review did use GPS (which includes both volume and intensity metrics) to monitor training load (Gibson et al., 2018; Fitzpatrick et al., 2018). Of these two studies, Fitzpatrick et al., (2018) used an individual MAS training protocol to track change in physical testing and reported moderate to very large correlations between a range of volume and intensity markers measured by GPS variables (eg, total distance and high-speed distance based upon MAS) with changes in aerobic performance. In contrast, Gibson et al., (2018) found only small changes in performance, perhaps due to the short duration of the study (5 days) and therefore it is difficult to evaluate the usefulness and generalisability of the TL measures observed in this specific study into other cohorts of players. Overall, it is evident that an increased volume to training provides players with stimuli which may in turn improve players aerobic performance. However, it should be noted that the intensity of such training is probably more important than mere increases in volume and therefore a measure of intensity when objectively quantifying an individual's training load should be observed. Currently within elite youth soccer there is a lack of studies which attempt to quantify this and therefore in chapter 5 of this thesis an elite youth soccer cohort will be monitored across a season long period to understand how such training load affects such physical development.

Of the studies which measured changes in lower body strength and power (n=13) eleven used CMJ to detect any changes in physical performance (Gibson et al., 2018; Malone et al., 2015; Paul et al., 2018; Los-Arcos et al., 2015; Williams et al., 2012; Silva et al., 2011; Abderrahman et al., 2012; Perroni et al., 2019; Lopez- Segovia et al., 2011; Sports and Matovic 2014; Francioni et al., 2016) while two studies (Morris et al., 2018; Silva et al., 2011) used more strength based tests (IMTP & Isokinetic Dynamometer). CMJ performance was generally higher at the end of pre-season in comparison to the start, with five studies providing positive correlations between training exposure and jump height (Abderrahman et al., 2012; Peroni et al., 2019 Gil-Rey et al., 2015; Noon et al., 2015; Malone et al., 2014). Increases in jump height therefore seemed indicative of increased training and match involvement. Previous research has widely used the CMJ as a field test to evaluate the muscular power of lower limbs in various sports, including youth soccer (Petrigna et al., 2019). It is widely used due to its

simplicity to perform and its closely related movement pattern to vertical jumping during youth soccer match play, with recent research widely recognising it as the standardised lower body power test (Claudino et al., 2017). Furthermore, it has been concluded as a reliable and valid test (Claudino et al., 2017; Taylor et al., 2012) using output measures such as jump height and eccentric displacement. As such, use of CMJ could be used to assess a youth soccer players neuromuscular performance, although it is imperative to ensure the correct variables are measured from the jump.

As speed is widely accepted to play a crucial role in soccer performance (Faude et al., 2012; Jeffrey et al., 2018) the ability to test speed has become standard within soccer testing batteries. The studies in this current review investigated sprint performance ranging from 5 to 40m. All distances (5-40m) seem to be equally important in soccer, although short sprints and accelerations (eg. 10m) occur much more frequently than longer sprints (eg. 40m) during match play (Haugen et al., 2014). However, in this review, there were only significant negative correlations observed between individual decreases in 30m sprint time from the start of pre-season to the end of preseason (Abderrahman et al., 2012; Los-Arcos et al., 2015). Perhaps an explanation for these findings across the pre-season phase in comparison with the in-season phase of this study could be as a result of the increased training load and intensity, and as such an increased high intensity stimulus was exposed to the individuals this resulted in improvements in speed performance. Whereas during the in-season phase, whereby the training load is directly influenced by the involvement of competitive matches, an increase in sprint capability may not systematically be observed in this period. This is partly due to the focus of this to ensure physical readiness for match play, however when the findings of chapter 3 demonstrate that coaches do not mind if players go into a match under fatigue in a developmental program so an further understanding as to why players are not improving their sprint capabilities may be required.

In relation to the use of the 30m sprint test to assess speed-based changes, a recent systematic review (Altman et al., 2019) concluded that maximal sprint testing (>30 m) could be used. There were inconclusive findings in relation to all other methods to assess sprint ability except for 40m sprint testing in this review. In addition to this, when the relationship

between the results of a 30-m sprint test and the maximal sprinting speed during matches, a large relationship was observed (Djaoui et al. 2017). This seems sensible as Silva et al., (2013) concluded that high intensity and sprints distances players performed within matches were increased in correlation with a decreased time in the 30m sprint test. These findings further suggest the function of the 30m sprint test as a measure of maximal sprint ability. In summary, it seems evident that using a sprint test >30m is an appropriate measure to determine sprint ability in elite youth soccer players.

Five studies analysed change of direction (COD)/agility performance, with three using the arrowhead agility test (Morris et al., 2018; Noon et al., 2015; Silva et al., 2011) and two studies using a slalom test (Sporis and Matkovic, 2014) and COD zig zag test (Arrgui-Marin & Garcia Tabar, 2019) respectively. Of the studies which used the arrow head agility test performance only one (Morris et al., 2018) found significant differences in COD ability, although within this analysis it should be noted that it was matched on maturity status with control groups. In both Noon et al., 2015 & Silva et al., 2011 there were a lack of significant correlations between fitness and training load variables. In relation to the COD zig zag test there were no significant relationships between training load and change in test performance. Perhaps the lack of significant findings is due to the slightly lower reliability of agility tests compared to other physical testing categories which could be attributed to the complexity of such tests, incorporating both physical and perceptual aspects of speed (Altman et al., 2019). For instance, several parameters can potentially be examined in such tests: response time at the start, decision making time and the response accuracy. Furthermore, there are a large variety of change-of-direction tests, perhaps the large differences in test design highlight the lack of an accepted gold standard (Chaouachi et al., 2012).

Limitations

We believe that more research is still required which accurately monitors TL in conjunction with sensitive tests to detect performance changes. For instance, when evaluating the application of the outcomes of this investigation, there are many limitations which must be considered before applying the findings into practice. The articles included in this review reported changes in physical assessments across a diverse range of training periods (ranging

from 5 days to 2 consecutive seasons). This range of time periods is likely to affect the extent of the aerobic and neuromuscular adaptations that occur within the athletes included in the samples. This makes it potentially difficult to make firm conclusions about the relationships between specific aspects of the training load prescribed in the studies and the change in test performance. The impact of this potential factor on the findings of our manuscript could have been reduced by the application of tighter inclusion criteria, around the adaptation (period) of the papers that were analysed though this would have further reduced an already small volume of manuscripts to evaluate. Other more general factors, such as theoretical and conceptual limitations to accurate training load quantification, the general approach to utilising detailed training load methods, a lack of focus on analysing individual responses compared to group responses and the appropriateness of each individual test may also impact our findings. This perhaps highlights the necessity to improve current approaches which both quantify TL and measure physical development of professional youth soccer players in research. Within this review there is also a lack of consistency between the measures included, which limits the ability to cross comparison between studies.

Conclusion

The present review was the first to provide a systematic evaluation of the association between training load and physical development using the current literature available within professional male youth soccer players. Both external TL (total distance, high speed distance, accumulated duration) and internal TL (RPE, TRIMP) measures were found to be associated with improvements in physical test performance across both pre-season and in-season phases. In addition, field-based testing was found to be sensitive to changes in physical performance for aerobic capacity, lower body power and strength and sprint performance. However, limited sensitivity to change was found when assessing player agility performance. Future research in this area should look to enhance our understanding of the dose-response of TL (particularly internal TL) with changes in fitness across different age groups in professional male youth soccer. It would also be pertinent to examine whether enhancement of these physical quality improves a player's chance of making it as a senior professional player. Therefore, as this review evidences, there is a lack of objective information within the

literature which accurately quantifies and analyses the effects of youth soccer training in terms of improving players physical qualities. Further research is required to provide a consensus on methods of tracking and monitoring tracking physical changes in elite youth soccer, which chapter 5 of this thesis will attempt to address. In doing so, more precisely quantifying the training load which players are exposed to, should give both researchers and practitioners a better idea as to the performance changes which are observed as a response of specific training load. The findings of this review have provided information to inform the methodology used within chapter 5 to allow the systematic training programs within youth soccer to be thoroughly examined for effectiveness.

CHAPTER FIVE

IS THE CURRENT TRAINING LOAD EFFECTIVE IN RELATION TO THE PHYSICAL DEVELOPMENT OF SOCCER PLAYERS ACROSS A SEASON LONG PERIOD? HOW DOES THE EXPOSURE TO MATCH-PLAY INFLUENCE THE PHYSICAL DEVELOPMENT OF YOUTH PLAYERS?

Introduction

Within chapter 3 it was evident that coaches believed that physical development was a key component of successful transition of players to the first team. As such it seems important to understand objectively what physical development looked like in practice. In addition, using the findings of chapter 4 it was evident that little research had been conducted into the long-term physical development of youth soccer players across a season-long period. This study therefore attempts to use the findings of chapters 3 and 4 to analyse the training program and its effect on physical development in youth soccer.

With it being evident from chapter 2 (review of literature) that soccer is characterised by high intensity, intermittent activity which yields energy from both anaerobic and aerobic pathways (Drust et al, 2000) the training programs which youth soccer players are exposed to should aim to improve the capabilities of both components of fitness. Furthermore, to effectively perform the required physiological actions within a soccer match, individuals need to have adequate levels of aerobic fitness (da Silva et al, 2010). Teams that have higher aerobic capabilities have been shown to demonstrate an increased distance covered during match play (Bangsbo & Lindquist, 1992) and in addition, having an improved league table position at the summation of the competitive season (Krustrup et al). This increased aerobic capacity, and more specifically VO_{2max} performance, has also been found to be directly linked with improved total distance (up to 20%) and number of sprints (100%) during match play which was correlated to increased ball involvements per player (23%) (Helgerud et al., 2001). As such, the ability to design training programs which aim to improve aerobic capabilities in

soccer, and in addition, implement sensitive physiological tests aiming to monitor their capabilities seems important to both coaches and practitioners.

The development of an individual players physical and technical capabilities is achieved by systematic training programmes which inherently promote several changes within the brain and other physiological systems (Gordan & Bloxham, 2016). These adaptations ultimately facilitate improvements in relevant skills (physical, technical and tactical) and subsequently in match performance. To understand the adaptations that have occurred within the individual, it seems sensible to monitor the effectiveness of a training program. When designing respective training programs, it should be noted that there is substantial evidence that match load values are significantly higher than that of training load values. The role of match play within the training process should therefore not be overlooked in terms of its importance for the development of aerobic capacity in soccer players. For instance, comparisons between total distance (e.g. < 7 km v ~10-13 km) (Bangsbo et al., 2006), high-speed running distance (e.g. < 300 m v > 900 m) and sprinting distance (e.g. < 150 m v > 200 m) (Di Salvo et al., 2010) for matches in comparison with training further evidences these ideas. This is vital when considering previous evidence demonstrating significant positive correlations between the individual in season playing time and aspects of physical performance including sprint performance and muscle strength (Silva et al., 2011). This may suggest that competing in match-play regularly is an important component of any strategy to improve the physical status of the developing player. This is due to the notion that playing matches provides increased work at high intensities that will have physiological benefits leading to adaptations to individuals' capabilities which non starting players may not therefore be exposed to.

As soccer playing squads can involve anywhere up to twenty-five players, discrepancies between starters and non-starters could lead to differences in physical capacities and profiles regarding soccer specific components of fitness. Individuals who are non-starters in games will not receive the same physical stimulus as starters and as such could be at a disadvantage in relation to their physical fitness (Anderson et al., 2015). There is currently little data available that tracks the physical development of players and attempts to relate to the involvement in competitive match-play. As a result, the long-term impact of low exposure to matches is unknown. This may create a difficult situation for sports scientists with regard to

replicating match load for non-starting players to enable maintenance of fitness levels. In order to understand the demands the players are exposed to over a chronic period it is necessary to quantify the chronic training load, including match play, in relation to relevant markers of physical performance. This would clearly identify the role that match play may have in the physical development of the young player and help improve future player development strategies on an individual player basis.

The quantification of TL is generally based on both external and internal indicators of effort intensity (Buchheit, 2014). Multiple studies have also demonstrated that training and match exposure (duration in minutes) show associations with improved aerobic fitness (Los Arcos et al. 2014; 2015; 2017). Within chapter 4 of this thesis, it is evident through the systematic review that previous studies within elite youth soccer have attempted to assess the relationship between longitudinal changes in TL and physical fitness. However, within these studies it is clear that there has not been a thorough examination between the relationship of TL measures and changes in aerobic fitness, particularly across a longitudinal period. There are a limited number of studies across a range of other sports which attempt to provide dose-response data between internal TL measures and aerobic fitness which have been detailed in chapter 4. A deeper understanding of how training load across specific durations of training periods is still required, to give a better understanding of how said training load affects aerobic fitness in elite youth soccer players is required.

In contrast to physical training, it is important to also understand that the lack of exposure to required stimuli perhaps may induce detraining in an individual. This is commonly known as the principle of training reversibility. In regard to factors which cause training reduction or cessation the following, such as illness, injury, travel or vacation may often interfere with an athlete′s training process (Carling et al, 2014). It seems important to ensure that the training stimulus which a player has received is sufficient to ensure that there are not losses in training induced adaptations.

The physiological development of players is clearly highly complex and requires a long period of time. As elite youth soccer players are going through a long period of physical development, the demands of soccer at youth level are far less than elite adult soccer. There

are differences in all variables such as total distance and power assessment when comparing youth with adult soccer and with recent studies suggesting that age, morphology, and physical fitness are influential parameters of football performance in elite-level football players (Rebelo et al, 2012;2013). At present the literature surrounding this mainly focuses on elite first team level with little evidence/reporting of how this differs to the academy development phase of soccer. With this in mind, the aim of this study was to quantify the accumulative training and match load across an annual season in elite academy soccer, which will allow its effectiveness in relation to the development of internal physical performance across this time frame. An understanding of the changes in physical fitness across the season can therefore be understood. Furthermore, the aim of this research was to understand how training influences players physical performance and the specific key parameters which can provide correlations to allow for an understanding between training load and changes in fitness with the submaximal YoYo IE2 fitness test across an elite youth soccer season. This will allow us to identify players who participated in multiple tests in which an evaluation in how their physiology changes across the season can be understood. In addition, an understanding of how much of the physical stimulus comes from the training prescription and how much comes from matches in periods of two, four and six weeks prior to the physical testing period was analysed.

Methods

Training load data was collected from elite outfield soccer players from an English premier league teams' academy (category 1 status), U15 & U16 (n=12; 15.2 ± 0.8), U18 (n=22; 16.7 ± 0.8) and U23 (n=15; 18.2 ± 1.4) were monitored over a 40-week period during the 2019-2020 soccer season (curtailed due to global pandemic so no data collection for March to May 2020). The study was approved by the department of ethics at the University of Birmingham in line with the declaration of Helsinki. The gatekeeper provided full consent to use the training load data which is collected as part of normal daily practice at the club and where it was necessary. In addition, parental permission was obtained for players <U18 along with informed consent, which was provided by the players themselves. Players trained 4 ± 2 times per week, with sessions ranging between 45 - 120 min in duration depending on the day of

the week. The content of each training session was determined by the team's technical soccer coaches and fitness coach in line with the physical, tactical and technical objectives for each given session. This study did not influence any sessions or matches in any way just as it did not influence the inclusion or exclusion of players in training sessions or games. The full duration of each training session was used for analysis, including the team warm up, top up sessions and rehabilitation sessions with both the physiotherapists and fitness staff. All training drills with the data collection were carried out at the soccer club's outdoor grass training facilities. As shown in Table 5.1 all players completed 1 - 3 gym-based sessions per week, typically consisting of 30 minutes lower body strength, upper body strength or whole-body power-based exercises. The microcycles for each team consisted of slightly varied weekly training schedules which can be found below in Table 5.1 (15/16s, 18s, 23s).

Table 5.1 Typical weekly schedule for each squad.

		Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
15s &16s	AM	TRAINING GYM			TRAINING		MATCH	
	PM		TRAINING		TRAINING			
18s	AM	TRAINING GYM	TRAINING GYM (UB)	TRAINING GYM		TRAINING	MATCH	
	PM							
23s	AM				GYM		TRAINING GYM (UB)	TRAINING
	PM	MATCH	RECOVERY		TRAINING	TRAINING		

To track changes in aerobic fitness as a result of the training stimulus the YoYo Intermittent endurance test level 2 – submaximal version was implemented. The test was implemented 8 times across a 40-week period of training as follows first (E1) early July; second (E2) early September; third (E3) early November; fourth (E4) mid-December; fifth (E5) early January; sixth (E6) mid-February; seventh (E7) early March; eighth (E8) late March. All YoYo Intermittent endurance test level 2 were performed at 10:30 in the morning prior to pre training in an indoor sports hall. To remove the effect of match-induced fatigue, and allow for freshness, the test was assessed on the third day post-match (usually a Tuesday which was approximately 72 hours post-match). The under 18 squad were the only participated in testing periods E5-E8 in addition to the E1-E4 testing. This was due to a change in fixtures in the aforementioned periods for the U15/16s and U123s squads, whereby the coaches did not want their players to be participating in a physical test with the increased fixture demand.

This seems odd as the coaches within the interviews of chapter 3 described that they did not mind if players participated within the game under slight fatigue. The nature of this study is to therefore understand how these subjective ideas by the coaches are reflected in practice for the long-term physical development of soccer players.

Players from different positions on the field were tested: wide defenders (8), central defenders (12), central midfielders (11), wide midfielders (9) and attackers (8). Both short and long-term injuries >28 days were included from this study as this will be of interest to see how the decrease in external training load may affect the internal response when completing the YoYo IE2. Under 18s performed more tests on average per player across the season in comparison with both the under 15/16s and under 23s squads. Players were then also split into 3 groups for the analysis; starters, fringe and non-starters. This was based upon the percentage of games they were involved in within the season. Starting players started ≥60% competitive games, fringe players started 30-60% of games and non-starting players started <30% of games.

Training and Match Data Collection

The external and internal load of all field-based training sessions and competitive matches during the 40week training block was monitored using 10Hz Global Positioning system StatSports Apex system (GPS) and heart rate Polar H1 system (HR) respectively. The GPS device provides position, distance and velocity data and has been previously validated by Beato et al, (2018) against the 18Hz unit. Each player wore the device inside a custom-made vest provided by the supplier. The device was positioned across the upper back between the right and left scapula with it positioned in such way that the GPS antenna can be exposed to access the satellite for a clear reception. To eliminate interunit variability, all players were assigned their own specific device which they wore every time they either completed a training session or were involved within a competitive match. Devices were activated prior to the session to ensure that the satellite was locked onto the unit prior to data collection each day. Following on from each training and match the GPS data was downloaded using the respective software package (apex team series) from StatSports onto a personal computer and exported for analysis. Total duration, Total distance, High speed distance (>5.5m/s) Sprint

distance (>7m/s), High intensity accelerations and decelerations and % of time spent in HR Zone 5 (83-89% MHR) & 6 (>89% MHR) were chosen for analysis in this study. Total time and total distance were chosen as the volume based external load measures as an accumulative measure of total loading. The velocities that were chosen for the intensity measures high speed distance and sprint distance were chosen as they replicate the absolute thresholds within the literature 5.5m/s and 7m/s (Martinez-Carbero et al, 2018). The physiological intensity of all training sessions was expressed relative to a %HRmax. The players' maximum heart rate was determined by an incremental maximal field-based run at the start of the season and updated if a higher maximum HR was achieved across any match or training session throughout the season and all data recalculated.

The training load variables assessed were as follows; Number of Matches Played, Total Duration of Training, Total Distance Performed, and Total High-Speed Running, Total sprint distance and HR Training Above Zone 4. The HR training above Zone 4 represents the total duration of training occurring in HR Zone 5 (83-89% MHR) & 6 (>89% MHR).

YoYo Intermittent endurance test Level 2 (submaximal)

To understand the changes to physical fitness as a result of the training load it is important that the tests are accurate and valid in doing so. As mentioned above the following test was used to do this to understand aerobic changes within the study; The Yo–Yo IE2 test submaximal version which has previously been validated by Gibson et al., (2018). The test lasts for 4 min and consists of repeated 20-m shuttle runs at progressively increasing speeds dictated by an audio bleep emitted from MP4 player. Between each shuttle the players had a 5-s period of jogging around a marker placed 2.5 m behind the finishing line. The termination of the test was after 4 minutes with heart rate recordings during (average of last 30s) and in recovery (60s post termination) from a given number of shuttles was used as a marker of performance. Heart rate was recorded by a Polar T1 (Polar Electro Oy, Kempele, Finland) placed around the chest for continuous heart rate recordings throughout selected stages of the test. All testing sessions were performed indoors on an artificial surface on a 2x9 20 m running lane marked by cones. GPS was turned on prior to going indoors to allow for the satellite signal to pick up on the unit.

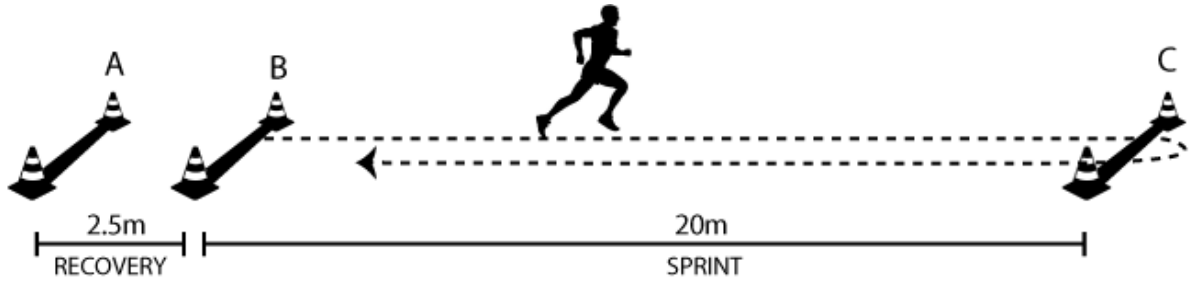


Figure 5.1 Layout of the YoYo Intermittent endurance test level 2. Figure adapted from www.yoyotest.com

Statistical Analysis

The data presented in the test and figures within this study are presented as means (SD) unless stated otherwise. The assumption of normality was observed using model residuals in the program R, UNIX platform; r-project.org using the Shapiro-Wilk test. Firstly, to understand the interaction between %HRmax from the submax YoYo and the test variables-, one-, two- and three-way ANOVAs were conducted (SPSS Version 2.0). Associations between training load variables and changes in aerobic fitness were assessed using Pearson's correlation coefficients and linear regression analysis. The strength of the correlations were observed using Smallest Worthwhile Change and Minimal Detectible Change. To further understand and establish the effects of starting status, and the way in which a player receives their training exposure (through matches or training) it was important to scale the total distance to 2000m to allow for comparisons at each time period to be made. In order to aid interpretation of model coefficients, total distance was scaled to 2000m to allow practitioners to understand the relationship between independent and dependent variables on a scale that is more meaningful to training volumes they see in practice.

Results

There were significant differences when the effects of starting status (starters, fringe, non-starters) were accounted for in relation to the test (see figure 5.5). It is also clear from table 5.2 and figure 5.2 that the under 18s participated in the greatest number of physical tests across the season. Figure 5.2 shows the distribution of the tests across the season showing squad participation and the number of players which were involved in each respective test showing that Under 18s were the only players to participate in tests E5-E8. Figure 5.3 below demonstrates the normal distribution of the Heart rate measures for each squad. Figure 5.4 within the results section gives a detailed description of how the influence of the team which a player is involved in changes the output of the physical test which provides an understanding of the effects of specific training stimuli.

Table 5.2 Average number of YoYo IE2 submax tests performed per player, per squad, across the full testing duration.

Team	**Average Number of Tests across season**	**Standard Deviation (Number of Tests)**
Under 15/16s	3.2	1.1
Under 18s	4.4	1.9
Under 23s	3.3	1.1

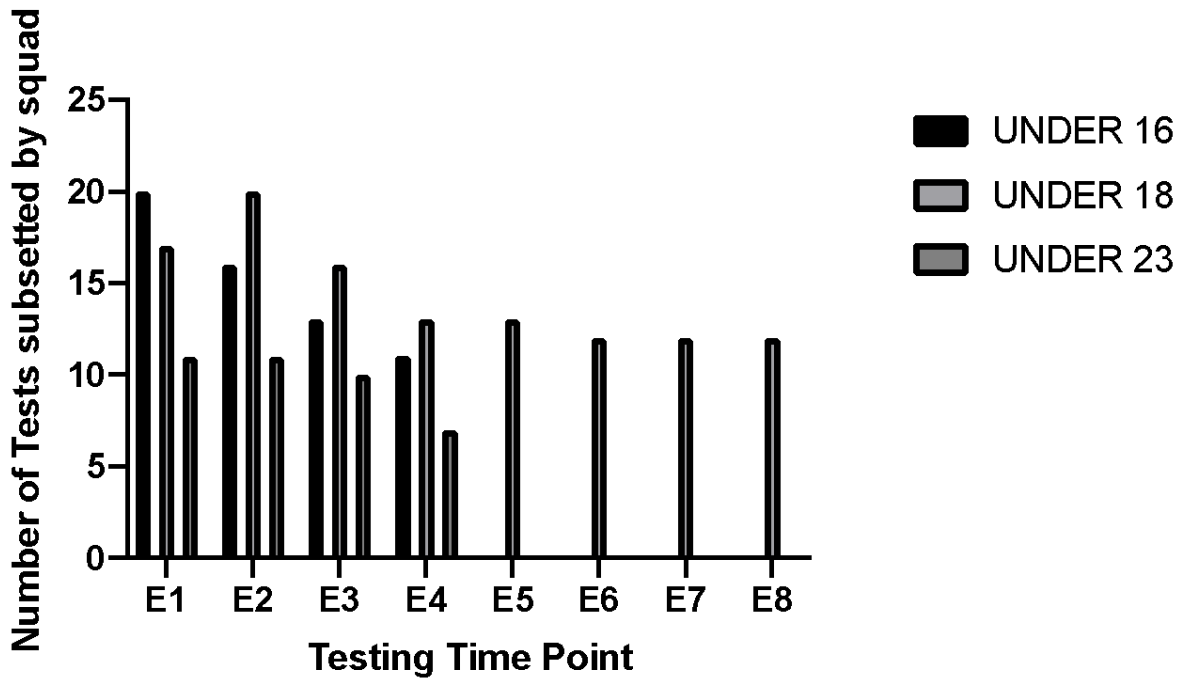


Figure 5.2 Distribution and count of YoYo Intermittent Endurance level 2 submax tests performed, per squad, across the full testing duration.

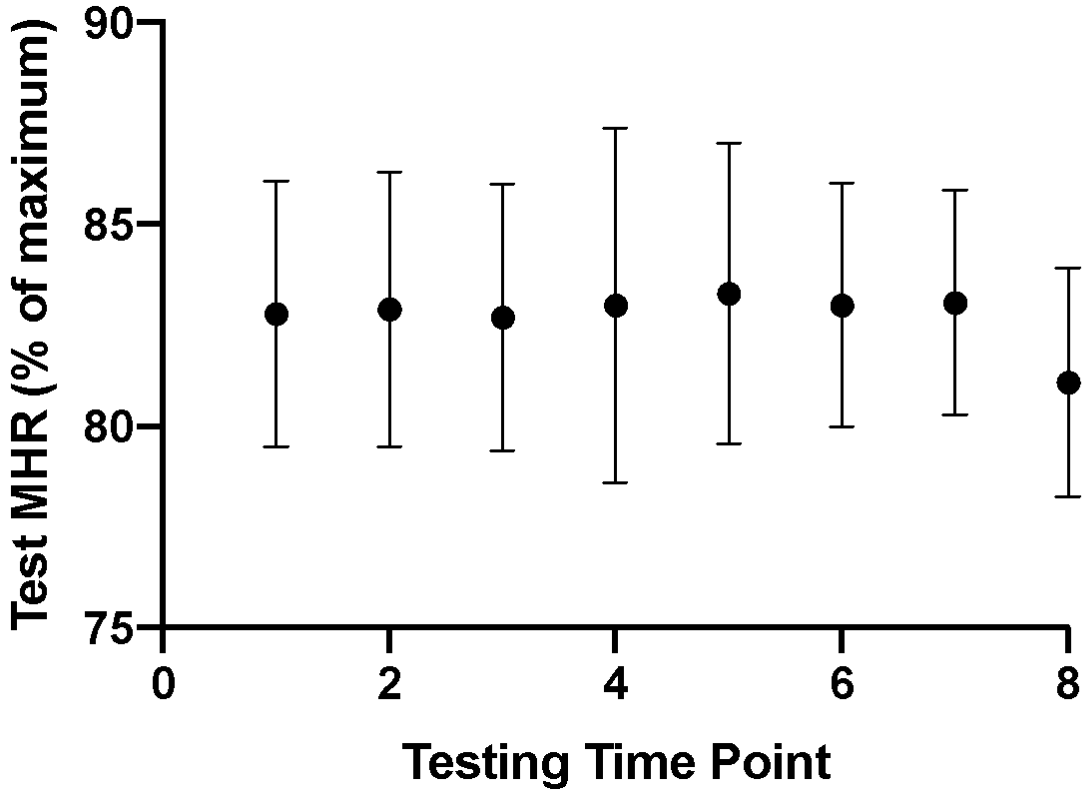


Figure 5.3 Changes in aerobic fitness across a season when combining under 15, 16, 18 and 23s squads.

What proportion of a player's physical stimuli comes from matches or training?

Table 5.3 demonstrates the averages for the key variables at the time points; two weeks, four weeks, six weeks and all the training load and match involvement prior to the test. In addition, gives an overview of the percentages on average across the season as to what percent comes from either training or matches (games).

Table 5.3 Mean (SD) for each of the key training load variables in relation to two, four, six weeks and all of the training load prior to the submaximal YoYo test.

Weeks Prior to Test	Average Total Distance (training and matches) (m)	Average Total High speed Distance (training and matches) (m)	Game Total Distance (m)	% of Total distance from games	Game High speed distance (m)	% High Speed Distance from games	Training Total Distance (m)	% Total Distance from Training	Training High speed distance (m)	% High Speed Distance from Training
Two weeks	48657.85 ± 17261.53	2050.29 ± 985.69	11143.67 ± 10417.17	23.1 ± 21.4	762.74 ± 807.39	37.2 ± 39.4	37514.19 ± 13141.89	76.8 ± 27.0	1287.56 ± 701.07	62.8 ± 34.2
Four weeks	93327.37 ± 28452.14	4048.55 ± 1605.34	19332.09 ± 14985.80	20.7 ± 16.0	1334.17 ± 1162.19	32.9 ± 28.7	73995.28 ± 21826.11	79.3 ± 23.4	2714.38 ± 1102.44	67.1 ± 27.2
Six Weeks	137829.71 ± 39720.80	5900.04 ± 2228.41	30409.43 ± 21839.87	22.2 ± 15.9	2056.46 ± 1638.37	34.8 ± 27.7	107420.28 ± 28357.53	75.8 ± 20.6	3843.58 ± 1407.76	65.2 ± 23.8
Full Duration between individuals' tests	155036.39 ± 90118.28	6674.53 ± 4262.49	32479.07 ± 31227.49	20.9 ± 20.1	2195.49 ± 2243.08	33.2 ± 33.6	122557.32 ± 67804.86	79.1 ± 43.7	4479.04 ± 2792.53	66.8 ± 41.8

How does the team which a player is involved in effect the changes in fitness?

Overall, the trends in regard to each team are largely similar, with figures 5.8 and 5.9 later in the results section giving specific detail showing that all squads have a negative association between total distance 6 weeks prior to the test with a change in %HRmax. We can observe from Figure 5.4 that the under 16s on average have a higher HR achieved in the test compared with both under 18s and under 23s. The main difference between the three teams as they all the lines are almost parallel is the intercept, which is where the line would cross the y-axis if the data was extrapolated. For the under 16s the intercept is highest (near 90%) and the slope is greater (TD_km has a coefficient of -0.04). 18s, The intercept for the under 18s is less (86.7%) and the slow is less as well (TD_km has a coefficient of -0.03). Again, as the figure below suggests, the intercept for the 23′s is less than the 18′s and the slope is the same as the 18′s (they had nearly parallel lines in the figure above) The intercept for the under 23s is less (83.8%) and the slope is less as well (TD_km has a coefficient of -0.03)

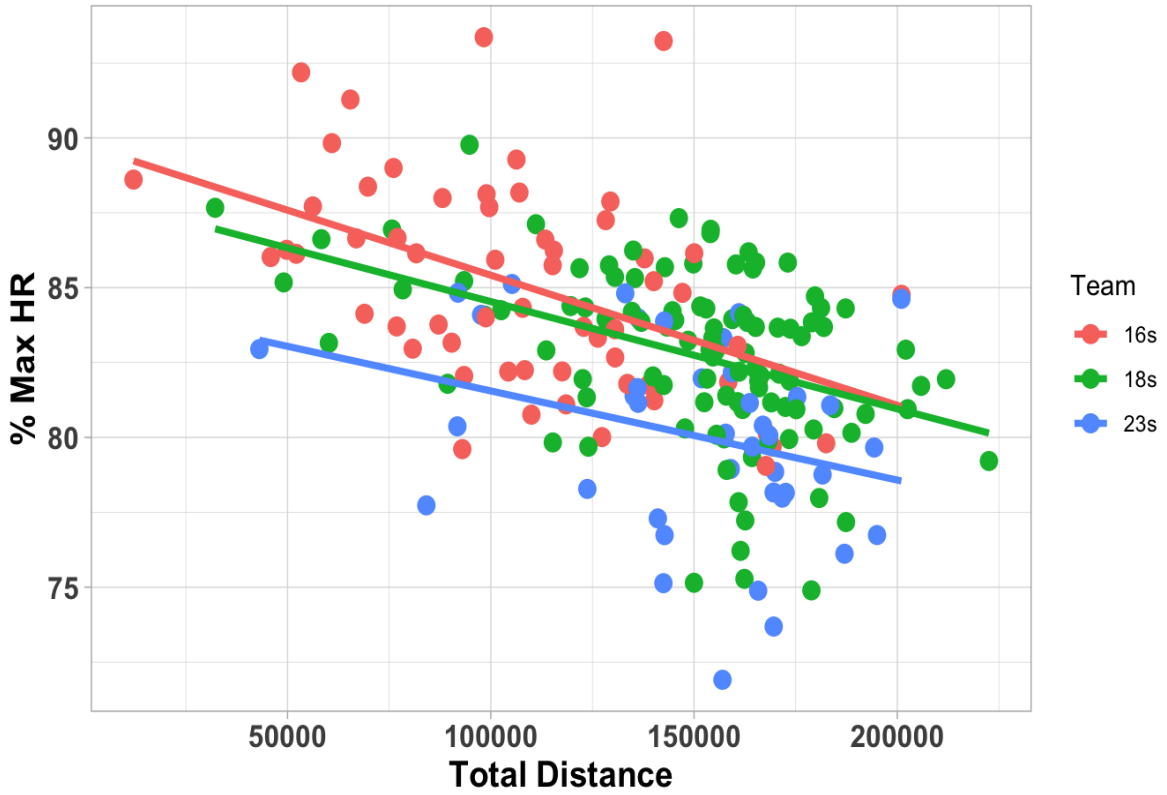


Figure 5.4 Relationship between MHR & Total distance accumulated 6 weeks prior to the test in relation to specific squad status.

How does starting status (the way in which training load is administered) influence the changes in aerobic fitness?

There was no significant effect for aerobic fitness changes when averages across all squads were combined and analysed across the season (figure 5.3). However, there were significant differences when the effects of starting status (starters, fringe, non-starters) were accounted for in relation to the test (figure 5.5). Starters (>60% Match mins) had a consistently lower max HR in the test across time, apart from (E1) which was the first week back of preseason, where all players were returning from an extended period of rest during the off season. All other time points (E2-E8) showed a significant difference between starters and both fringe (30-60% match mins) and non-starting players (<30% match mins) ($p=0.00$). There was no significant interaction between fringe players and non-starters ($p=0.53$).

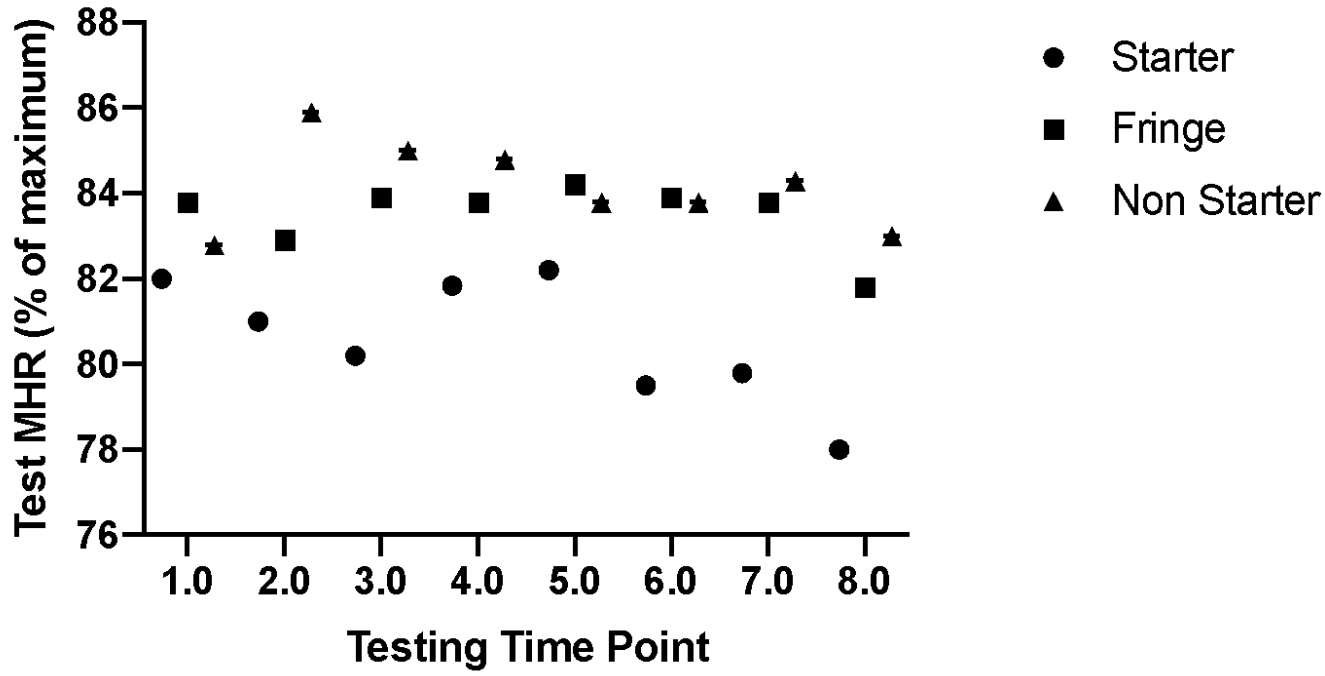


Figure 5.5 Changes in aerobic fitness across a season when analysing the data by starting status for all squads.

The relationship between training load, match involvement and changes in aerobic fitness. In addition, what is the relationship of the training load of two, four, six weeks and all of the previous training load occurring prior to the test and how does it impact the outcome of the test?

As mentioned in the methodology, it was important in aiding interpretation of model coefficients that total distance was scaled to 2000m, which would allow for practitioners to understand the relationship between independent and dependent variables on a scale that is more meaningful to training volumes which are observed in practice. Table 5.4 demonstrates the linear coefficients of each time period to explain this in more detail. -0.11 which is the value of match total distance coefficient, when scaled to 2000m for two weeks training prior to the test suggests that using this model, for every increase of 2000m in running during the two-week period observed there is a -0.11% decline in HRmax achieved in the test.

It is evident that as the coefficient value increased from 2 weeks to 4 weeks to 6 weeks, that the longer the individual goes without match exposure their %HRmax begins, on average, to

rise in the test (demonstrated by the intercepts). Conversely, the more training and matches a player completes their %HRmax declines. This is the same with the practice total distance whereby when a 2000m increase in training exposure elicits a decrease in %HRmax achieved in the test. These findings demonstrate that when both match and training exposure increases then a players' %MHR decreases in the test, and in contrast when a decrease of training and match exposure is observed then an increase in %MHR is observed. One point of not would be for future research to understand at what point this increased training in match volume plateaus in relation to the aerobic fitness improvements.

In table 5.3, this combines both training and games inclusive, therefore it was necessary to develop a model whereby an understanding of how games and training affected the test score irrespective of the combined total. For instance, we can see in table 5.4 that at six weeks, the Game coefficient is -0.18, suggesting that for every increased 2000m of Game Distance there is approximately a drop of 0.2% in %MHR. For the Practice coefficient, for every 2000m of practice distance there is also a decrease of -0.2% in %MHR. At both two and four weeks prior to the test the coefficients are similar, overall reiterating that the longer a player goes without playing matches then the further the reduction in aerobic fitness in the test. Furthermore, it is evident that the intercept increases from 2 weeks (86.2%) to 4 weeks (88.2%) to 6 weeks (89%). This could be useful in order to make predictions in the change in %Max HR and be used practically to help practitioners adjust training based on how much the player will be playing in games in the coming weeks.

Table 5.4 Coefficients at two week, four weeks and six weeks prior to the test, when scaled to 2000m.

Weeks Prior to Test	Match Total Distance coefficient scaled to 2000m	Training Total distance coefficient scaled to 2000m	Intercept
Two weeks	-0.11	-0.1	86.9%
Four weeks	-0.12	-0.2	88.2%
Six Weeks	-0.18	-0.2	89%

Table 5.5 Correlation matrix of each of the time periods of training between Total Distance and HSD metrics and %Max HR

Weeks Prior to Test	**Total Distance (m)**	**Total High speed Distance (m)**	**Game Total Distance (m)**	**Game High speed distance (m)**	**Training Total Distance (m)**	**Training High Speed Total Distance (m)**
Two weeks	-0.43	-0.37	-0.34	-0.3	-0.29	-0.18
Four weeks	-0.49	-0.41	-0.41	-0.35	-0.36	-0.23
Six Weeks	-0.51	-0.42	-0.45	-0.35	-0.41	-0.27
Full Duration between individuals' tests	-0.17	-0.2	-0.29	-0.26	-0.1	-0.1

It is evident that when separating the analysis in relation to the response of both training and matches it also seems evident more time spent training elicits improved fitness changes (see table 5.3). Furthermore, Table 5.5 demonstrates that as increases in the percentage of total distance and high-speed distance is through game involvement that there is a larger negative correlation the further away from the test. For instance, at two weeks the game total distance is -0.34 and at six weeks it is -0.45 respectively. The strongest relationships are observed at 6 weeks prior to the test; In relation to the % MHR achieved in the test, there is moderate negative correlations with Number of Matches Played (-0.33), Total Duration of Training (-0.45), Total Distance Performed (-0.51), and Total High Speed Running (-0.42), SPR (-0.32) and total a/ds (-0.4). There is a positive relationship between %Max HR and HR Training Above Zone 4 (0.23). In addition, figures 5.6, 5.7 and 5.8 demonstrate the linear relationship between training load measures and aerobic fitness. It was important to understand a variation in training load measures which changes in the fitness test to understand the relationship of both volume and intensity.

In relation to the duration prior to the test, the figures below (5.6-5.9) only demonstrate the results of 6 weeks prior to the test. Similar findings were observed when examining the relationship of training load at 2 and 4 weeks prior to the test, however the correlations were weaker. We can observe through figure 5.5 that it is evident that the increased number of matches prior to the test in which an individual is involved in, that there is a strong negative correlation suggesting it is a key factor in relation to the decrease in HR within the test. This also is evident in figure 5.3 whereby a starter has a much lower HR consistently throughout the season. The relationship for all time points are negative between % HR Max and external load training but the relationship is positive for HR Above Zone 4 and % Max HR. For example, if a player does more total distance, plays in more matches, and has more high-speed running, he has a decrease in % Max HR on his upcoming test, probably because he is getting more fit. Conversely, if the athlete spends more time in Zones 5 or 6 during training, he sees an increase in his % Max HR during the upcoming YoYo test. In relation to the % MHR achieved in the test and all of the training load prior to the test, The relationships at all of the training are weaker than at 2, 4 and 6 weeks.

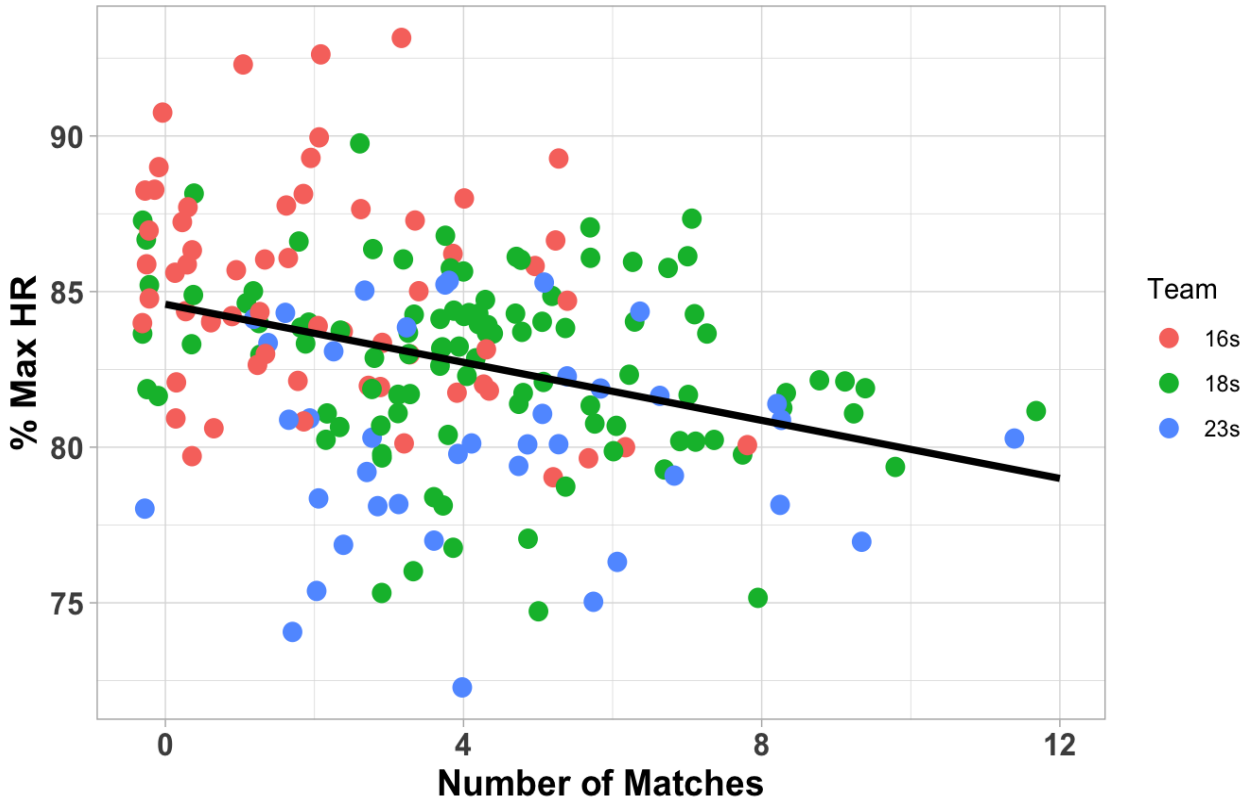


Figure 5.6 Relationship between MHR & Number of matches played 6 weeks prior to YoYo IE2 %HRmax.

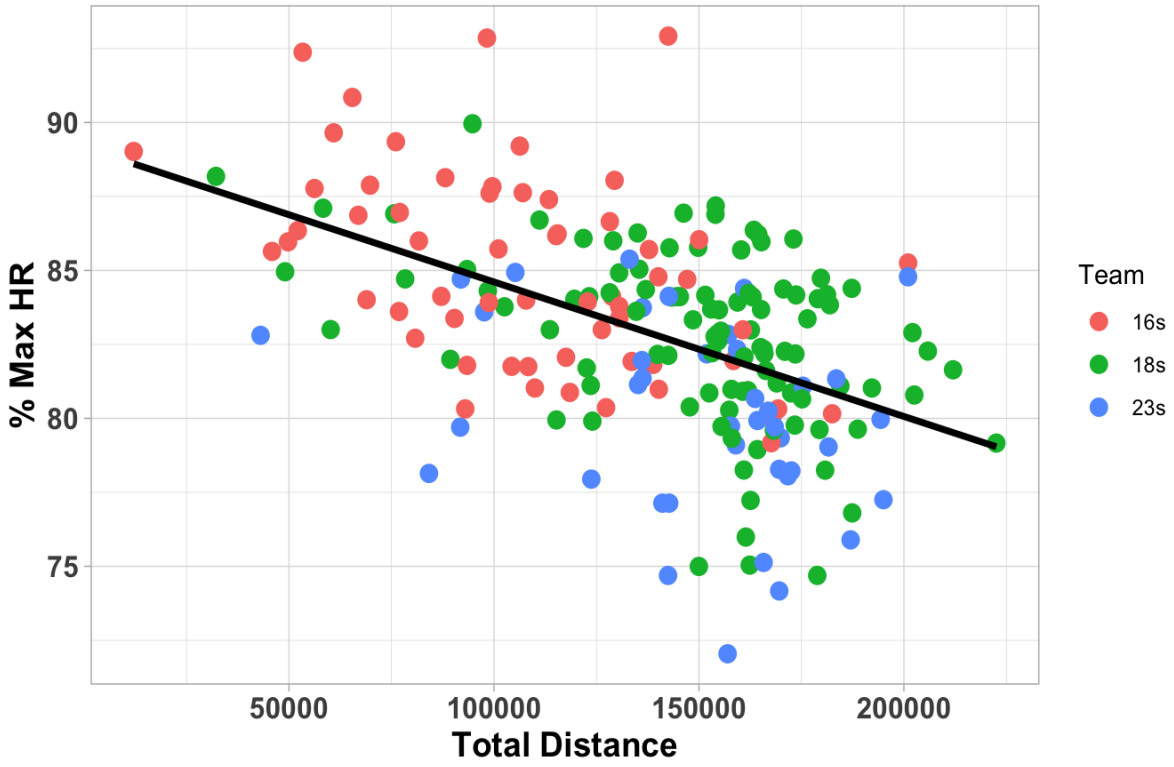


Figure 5.7 Relationship between MHR & Total distance accumulated 6 weeks prior to YoYo IE2 %HRmax.

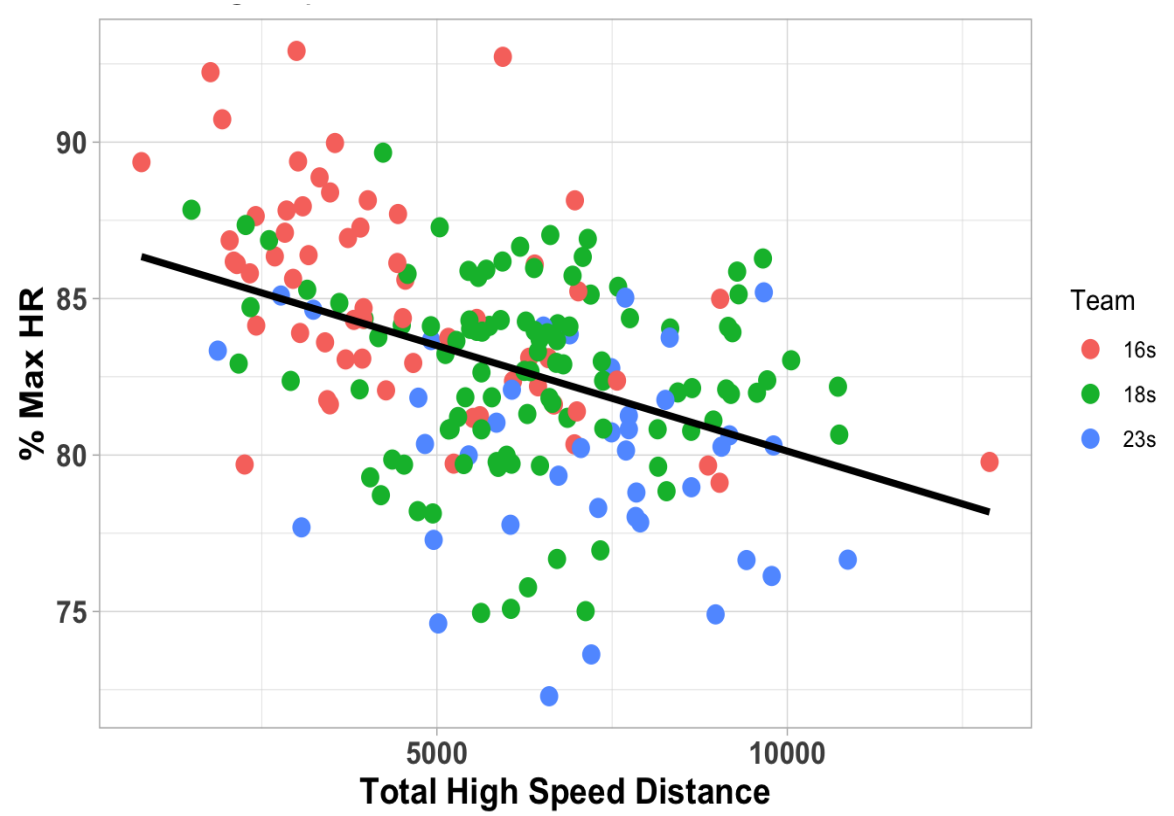


Figure 5.8 Relationship between MHR & Total high speed distance accumulated 6 weeks prior to YoYo IE2 %HRmax.

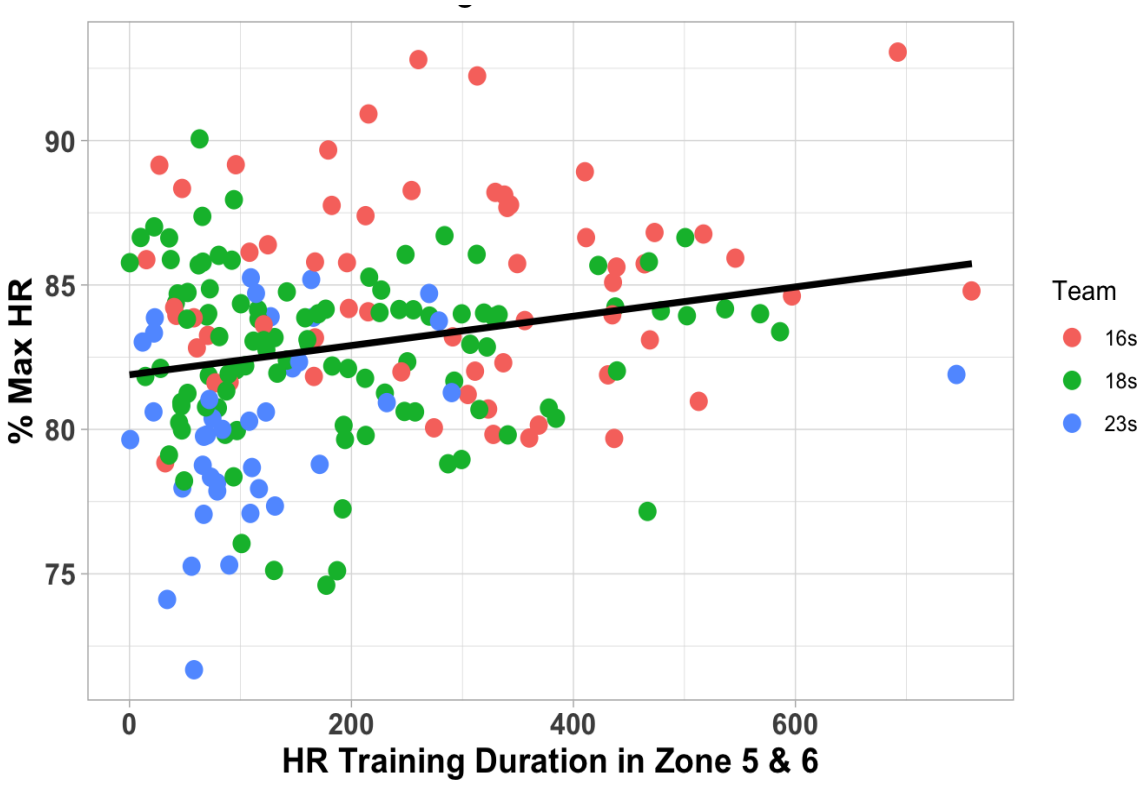


Figure 5.9 Relationship between MHR & HR training duration in HR zone 5 & 6 accumulated 6 weeks prior to YoYo IE2 %HRmax.

Discussion

The aim of the present study was to quantify the accumulative training and match load across an annual season of elite academy soccer, in order for its effectiveness in relation to the development of internal physical performance across this time frame to be examined. The findings of this study demonstrate that when the starting status of players (match involvement) was accounted for in relation to the examination of aerobic fitness; starters had a consistently lower HR response to the submaximal YoYo IE2 than both fringe and non-starting players across the season (except E1). In addition, there was no significant interaction between fringe players and non-starters. Within this study it was evident that the players training loads, from a whole group perspective were sufficient to maintain an aerobic capacity at a level adequate for elite soccer players. However, when looking deeper it was evident that

players who were involved in a larger proportion of match play that their aerobic capacity improves.

To further explore the causation to these findings, the second aim of this study was to understand how the TL prior to the test influenced player test performance. In addition, to identify key training load measures which provided an understanding between TL and changes in aerobic fitness measured by the YoYo IE2 test across an elite youth soccer season. As such, the relationship between TL and fitness was examined at the following time points; 2 weeks, 4 weeks, 6 weeks and all of the training prior to the test. Using Pearson′s correlation, it was evident that there were moderate negative correlations with number of matches played, total duration of training, total distance performed and total high-speed running. Furthermore, it should be noted that as the training load was examined further away from the test (i.e. 2 weeks < 4 weeks < 6 weeks), the correlation of each variable increased, perhaps suggesting that the longer a player goes without adequate stimulus, a physiological change is observed and as such, a decline in their aerobic fitness performance in the test. Conversely, this also suggests that the more chronic load a player undertakes (i.e. without getting injured) then they perform better at the test. At six weeks prior to the test, the correlations were strongest; number of matches played (-0.33), total duration of training (-0.45), total distance performed (-0.51), and total high-speed running (-0.42), SPR (-0.32) and total a/ds (-0.4) were found. This evidence suggests that the increased frequency along with accumulated distance from training and matches a player completes, the lower the players %HRmax in the test.

Findings from this study demonstrate that it is evident that for outfield players, who play full matches, the match days represent the most physically demanding days within a micro cycle (Di Salvo et al., 2007). For instance, the increased number of matches prior to the test in which an individual is involved in, there is a moderate negative correlation with test performance (-0.33). It is clear from this research that the systematic involvement in match play may be a useful strategy as part of a player′s physical program within elite youth soccer (Morgans et al., 2018; Di Salvo et al, 2007). In addition, it is well evidenced that the competitive demands of match play may impose strains to various physiological systems, specifically, the metabolic system (Metaxas et al., 2006). The specific actions within a soccer match can average between 10–20 sprints, a high-intensity run every 70 seconds, about 15

tackles, 10 headings, 50 involvements with the ball, and 30 passes, and changing pace and sustaining forceful contractions to maintain balance and control of the ball against defensive pressure (Sporis et al., 2008). High levels of physical stress are therefore imposed upon the player during this match play. Perhaps this explains why research in other team sports has concluded that individual match playing time (IMPT) has an influence on players' fitness during a full season (Goristiaga et al., 2008; Fitzpatrick et al, 2018). Conversely, another important notion is that for players who are receiving a lower exposure to matches, it may be necessary for these players to complete additional training to allow for the maintenance of their physical fitness. This may be important, as it was evident in this study that starters have an improved aerobic capacity than both fringe and non-starters consistently throughout the season. Previous literature has suggested that training can promote and develop soccer-specific fitness (Iaia et al., 2009; Bangsbo et al., 2008). In addition, Anderson et al., (2016) concluded that when players deemed to not be receiving appropriate match time are observed, training practices should be altered to include more emphasis on recreating high intensity demands of match play. This should be researched in future studies to attempt to understand how interventions could be put in place to close the gap between starters and non-starters (chapter 6).

Our findings demonstrated that players had similar fitness levels in test point (E1) which was the start of pre-season after a period of off-season rest. The first change in fitness across the season in relation to starters vs fringe/non starting players was at the end of the preseason period (E2). Perhaps this was as a result of coaches picking specific players even within the preseason phase to win matches and embed specific styles of play, so the squad was ready for the upcoming season. For instance, a coach may pick the best talent during this phase to ensure that his preferred 11 are used to playing together and ready for competitive match play. Previous literature regarding seasonal variation in physiological and physical fitness among soccer players (Tessitore et al., 2006) has demonstrated that there were significant changes (improvements) in the preseason phase with no further significant changes across the remainder of the season. This is in contrast to our findings whereby following the preseason period, in the test point E3 (October), which had a period of high fixture congestion prior to the test evaluation, we see a further decrease in HR response to the YYIE2 especially

in the starting players, with only a slight increase in contrast with both the non-starters and fringe players. The practical implications of such discrepancies are important for designing overall squad programs.

The decline in YYIE2 performance for non-starters and fringe players between E2 and E3/E4 could potentially be explained by the specificity of this competition schedule. Mohr et al., (2003) reported decreases in the ability to perform high intensity running during games when match exposure had been reduced in previous weeks. In addition, during this time, as it is in season, there may be limited specific fitness training as sessions are tailored towards match performance (lack of training stimulus for fringe and non-starters). Furthermore, it should be considered that if a player is consistently exposed to a lack of matches, potential detraining effects may be observed (Silva et al., 2011). Therefore, the completion of high intensity activity from the matches for players who are regularly involved is sufficient to activate molecular pathways that regulate muscle adaptations relation to aerobic performance may be important for these players (Egan et al., 2010). In summary, variations in the load were evident across periods of higher fixture congestion, causing an effect that was especially apparent between starters and fringe/non-staring player groups. This seems sensible given the obvious difference between the physical and physiological demands between training and matches (Morgans et al., 2014b; Anderson et al., 2015). Considerations should be made when entering these periods to ensure the management of players is adhered to.

The primary performance measure analysed within this study was aerobic performance, measured by the submaximal YoYo IE2 (see appendices for reliability). In relation to the chosen Yo-Yo test, the YoYo IE2 is widely used to evaluate the ability of soccer players to intermittently perform exercise and has been considered a sensitive tool to detect seasonal changes in the fitness of soccer players (Bangsbo et al., 2018). Our findings were in line of previous research whereby the YoYo IE2 test is sufficient to detect change in aerobic fitness across the season.

One consideration of this research is that it was conducted in elite youth soccer. As elite youth soccer possibly may be deemed to be a developmental program, it should be acknowledged that understanding what planning of a full seasons′ structure would look like to develop the

athlete could be interesting. In this study it is evident that the measure of success may be to get a player ready for playing in the first team, not winning on a Saturday (see chapter 3) meaning a slightly altered focus of the in-season phase should have perhaps been observed. This may be a limitation when planning training within this cohort to allow for optimal long-term development to occur, whereby planning for acute microcycles does not elicit maximal improvements to be adhered to across the whole squad long term. It is understandable why this is not completed however as a comprehensive analysis of applied training loads requires a large amount of systematic and meticulous work. In addition, Bangsbo et al., (2018) highlighted that the weekly training programmes may vary according to specific changes in player availability or competition involvement. The analysis in our study shows us information about how much training changes %HR max, which might help us better understand the volume of training athletes should do to either maintain or achieve higher levels of fitness during training phases with the season. As such, ensuring practitioners are understanding aerobic capacity, via changes in tests such as the one used in this study is key finding.

One final point to consider in this research is in relation to the effects of team status on the analysis. It is interesting that when observing this, the effects of team on the analysis we see that the 16s and 18s have a higher %HR max than 23s in the test (their intercept is higher than the population average) while the 23s have a lower % Max HR than the population average. 16′s (90%) come out as having an intercept higher than average (higher than the fixed effect value), 18′s (86.7%) is a little less than the 18′s and the 23′s (83.8%) have the lowest intercept. Perhaps this may be due to the 23′s being more fit to begin with or perhaps we are just seeing that younger player has higher heart rates and as you age your MaxHR and % of MaxHR comes down. The study of Strøyer et al., (2004) indicates that mean values of heart rate in young footballers during a match are higher than values noted in senior footballers. These findings suggest that HR response to similar exercise is increased at lower age groups. Furthermore, various research has shown that there is a large range of variability among individuals of the same age which may influence HR response to exercise (Iuliano-Burns et al., 2001; Di Luigi et al. 2004).

Limitations

Despite this study being novel in nature and practical application, the study is not without limitations. Due to the worldwide pandemic, a full season was unable to be analysed, the study was curtailed to 40 weeks in duration. It would have been interesting to gain a full seasons analysis in order to provide succinct analysis on how a players' aerobic fitness changes across the season in relation to the development phase of youth soccer. Only 8 weeks was missed however so there is a majority of the season analysed. Another issue that arose was due to the elite environment, we were unable to administer a maximal version of the YYIE2 test. As such we had to use a submaximal version. It is evidence that submaximal runs may be a plausible alternative from which physiological response data is analysed in addition to tri-axial loading from accelerometers that may indicate changes in movement strategies associated with fatigue (Buchheit et al., 2018; Fitzpatrick et al., 2019b). It should also be noted an elite soccer team would unlikely agree to perform a maximal fitness test during the competitive season. Furthermore, this data only represents the typical training and match strategy of one club and therefore generalisation to other clubs cannot be effectively made.

Conclusion

In summary, this is the first study of its nature to the authors' knowledge to extensively examine the response of starting status of elite youth soccer players in relation to aerobic fitness changes using both external and internal measures of TL across a longitudinal period. When the starting status of players (match involvement) was accounted for in relation to the examination of aerobic fitness, starters had a consistently lower HR response to the submax YoYo IE2 than both fringe and non-starting players across the season. It was evident that there were moderate negative correlations with number of matches played, total duration of training, total distance performed and total high-speed running. The negative correlation increased the further away from the test the analysis was conducted on (2 weeks < 4 weeks < 6 weeks). This evidence suggests that the more training a player completes along with an increased match involvement, then an increase in aerobic fitness was observed.

CHAPTER SIX

CLOSING THE GAP: A COMMENTARY ON MAINTAINING PHYSICAL FITNESS IN NON-STARTERS AND FRINGE PLAYERS COMPARED WITH STARTING PLAYERS.

Prologue

Following Chapter 5, whereby findings demonstrated that the systematic involvement in matches was important for the physical development of elite youth soccer players, it was important to implement an intervention study to aim to close the gap between 'starters' and 'non-starters' training exposure and in turn physical capability. An intervention was planned and implemented around February 2020 using the same cohort of players as chapter 5, however after only 3 weeks data collection was halted due to the worldwide pandemic. As such, this commentary was written to provide recommendations and, in a way, replace the intervention study that was planned as chapter 6.

From the findings of chapter 5, it is clear that match play participation may be a key stimulus for preparing players for the physical demands of competition, and in addition, an important factor of long-term physical development. As not all players are involved within match play, the differences in accumulative physical load between players can be challenging for fitness staff, as individuals are likely to receive different loading patterns, depending on whether they regularly start these matches. One method which is commonly used to increase the physical stimulus of players who have limited match-play exposure is to implement 'top up' conditioning sessions. These sessions may be immediately post-match, or the following day, with the aim to provide players with physical load in an attempt to replicate the demands on match play which they have not been exposed to due to not playing or only playing partial match minutes. The challenge therefore seems to be to not only prepare regular starting players for match play demands but also to concurrently maintain and develop squad fitness. This commentary therefore attempts to summarise the scientific rationale, current literature and practical recommendations to maintain and develop physical fitness in professional

soccer. The contemporary literature will provide preliminary methodological guidelines for coaches and practitioners to use, which would have been delivered in an intervention study if possible (see prologue) and give overall suggestions on the following topics:

- What are the most effective methods to maintain and develop physical fitness of players who are not regularly exposed to demands of match play?
- How effective are current 'top up' strategies in closing the gap between players who receive varied accumulative physical load?
- If current 'top up' strategies are ineffective, how should interventions be implemented to close the gap between players who receive varied accumulative physical load?

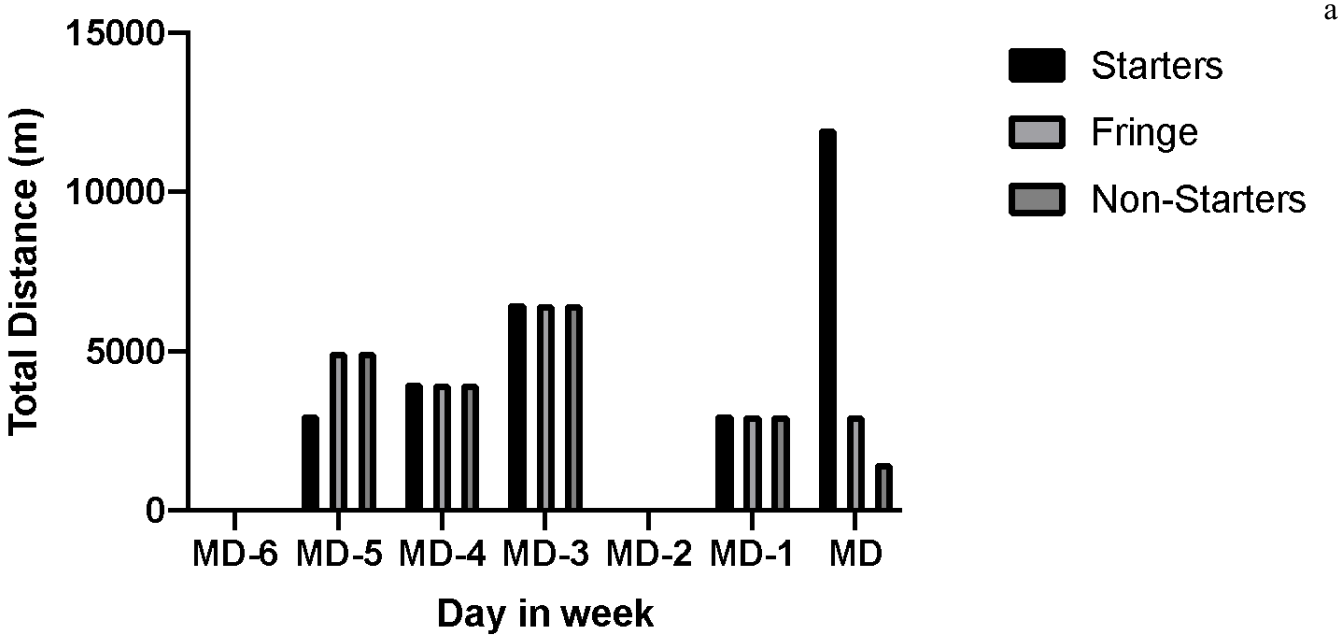
Introduction

As soccer has evolved, it has become common for playing squads to contain in the region of twenty-five players. With such high numbers, issues have arisen regarding the best methods to develop players' physical capacities. In addition, practitioners have to further ensure that individuals are not experiencing the detraining effects of low exposure to accumulative training and match load (hence total accumulative physical load). Current typical training practices may be sufficient to promote recovery and readiness for the following game however perhaps not optimal for long-term physical development. It is clear that individualisation of soccer players training load is required for optimal physical development. However, when applying this within a squad setting, challenges become apparent due to the variation in match stimuli experienced by different individuals.

Soccer is described as an invasion game that is characterised by an intermittent activity profile where high-intensity anaerobic efforts are interspersed between periods of low-intensity aerobic activity (Drust et al., 2000). As soccer is a team sport with multiple positions, the demands of the game differ for each player (Di Salvo et al., 2007). In addition, the chronic loading patterns of players within the same squad are typically varied depending on match

exposure. Therefore, it is imperative for practitioners to provide individualisation of accumulative physical load for each player. Chapter 5 demonstrates that match play is an important physiological stimulus for youth soccer players as regular starting players had a lower HRmax in the YoYo IE2 at regular intervals across the season in comparison with both fringe and non-starting players. It is therefore evident that for outfield players, who play full matches, the match days represent the most physically demanding days within a micro cycle (Di Salvo et al., 2007). Understanding these specific physical demands of match play is important to optimise the training process, as specific protocols and sessions can then be designed in line with these demands (Di Salvo et al., 2007). Anderson et al., (2015) found that when teams are required to participate in multiple (two or three) matches per week the match-day may account for up to >95% of a squad′s high-speed running (HSR) (>5.5m/s) and sprint distance (SPR) (>7m/s). In addition, the same author observed that although there was no significant difference for both total duration and total distance performed by the players, starters completed more (all $P < 0.01$) distance running at 14.4–19.8 km/h (91.8 ± 16.3 vs 58.0 ± 3.9 km; effect size [ES] = 2.5), high-speed running at 19.9–25.1 km/h (35.0 ± 8.2 vs 18.6 ± 4.3 km; ES = 2.3), sprinting at >25.2 km/h (11.2 ± 4.2 vs 2.9 ± 1.2 km; ES = 2.3) than nonstarters. S tarters also completed more sprinting ($P < .01$, ES = 2.0) than fringe players, who accumulated 4.5 ± 1.8 km. As such, it seems evident that players must be exposed to the exertion that is typically undertaken in match play as this is an important component of any strategy to improve the physical status of the player. Observations also highlight the potential for sub-optimal loading patterns regarding partial-match or non-selected soccer players.

a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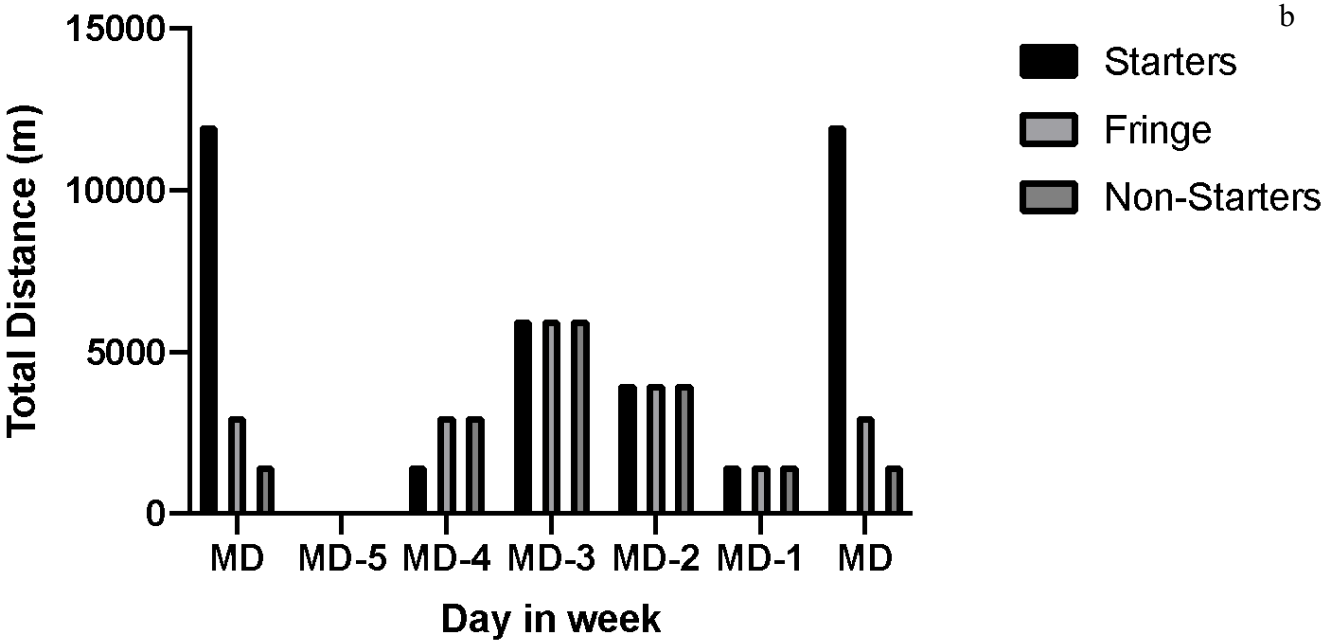
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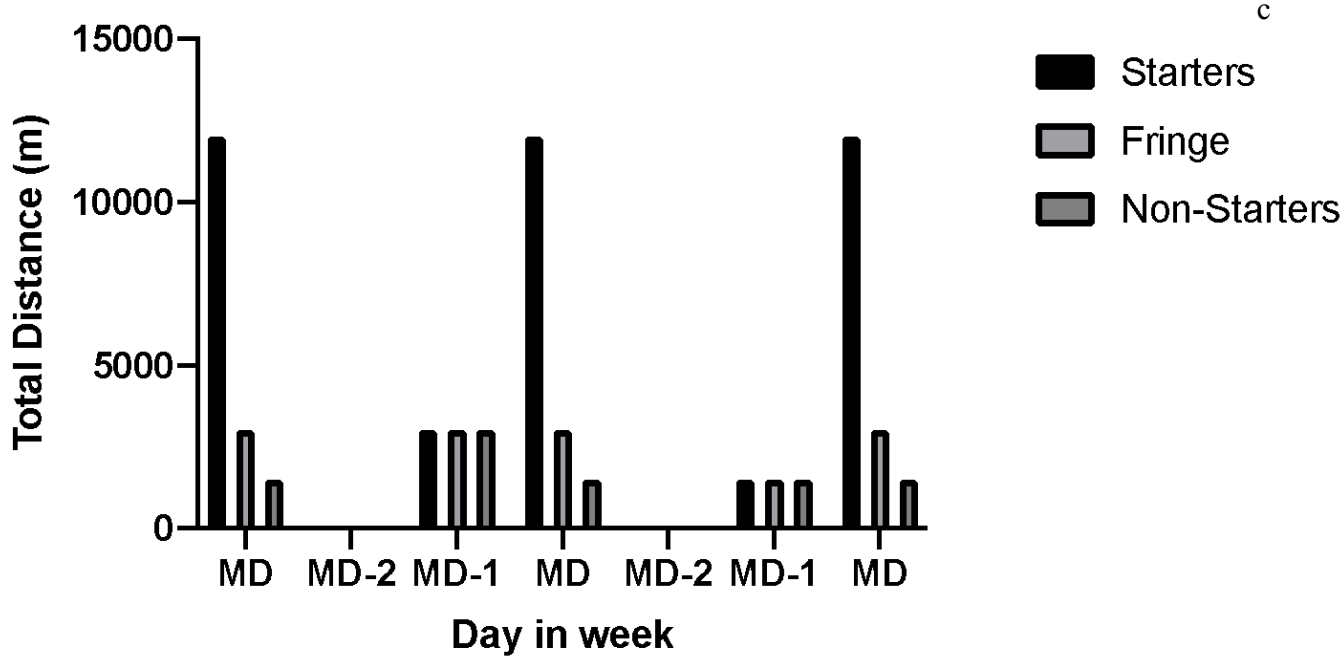

Figures 6.1 a, b & c adapted from Quantification of a typical one, two- and three-day game week by starting status (Anderson et al., 2015). Playing squad average total distance in training sessions during three different 7 -day testing periods. Figure 1a represents the typical structure of one game a week. Figure 1b represents the typical structure of two games a week. Figure 1c represents the typical structure of three games a week.

Figures 6.1 a, 1b and 1c demonstrate that if 'top ups' or conditioning sessions were not implemented, then the starters have a much greater physiological stimulus imposed upon them on a weekly basis in comparison with both fringe and non-starters. In chapter 5 it was evident that the number of matches an individual is involved in leading up to the testing period that there was a moderate negative correlation with test performance (-0.33). This reiterates the notion that the involvement in match play is a key factor in relation to the decrease in HR within the test. Furthermore, with chapter 5 also demonstrating that starters have a lower HR than both fringe and non-starters consistently throughout the season, it is clear that the systematic involvement in match play may be a useful strategy as part of a player's physical program within elite youth soccer. When applying these ideas across a season it should be understood that at different periods throughout the season there will be a different demand in regard to fixture fulfilment. Therefore, careful considerations of these findings should be made when playing two or three games a week as there could be some squad rotation which is required.

Squad rotation, which is defined as the practice of regularly replacing players on a team with other available players within the squad, allows for periods of rest and recovery (Carling et al, 2015). Even when there are periods of squad rotation, it is still highlighted that infrequent match exposure provides the player with much less physical stimuli. There are methods to reduce this, which is important, due the notion that there are negative adaptations associated with reduced loading patterns for players. Practitioners often employ methods such as implementing extra training sessions the day after a match or a top up conditioning session immediately post-match. These sessions are for unused players, partial match players and players not involved in the match day squad at all (Bucheit et al., 2019; Buckthorpe et al., 2019). The aim of these top up sessions is to compensate for deficits in physical loading for individuals who receive either no match-play exposure, or substantially less than that of whole-match players (Hills et al., 2020). Currently there is little data available that tracks the physical development of players across a season in relation to physical performance markers which attempts to relate these changes to the level of involvement in competitive match-play. An understanding is required as to the impact of low and high exposure to matches on physical development and as to how additional sessions (both top ups and extra training sessions) should fit within a micro cycle for players who are not involved in regular competitive match play.

For players who do regularly play a full match, chapter 5, along with previous literature demonstrates that the matches represent the most demanding day within the week in relation to total distance and high-speed distance variables (Malone et al., 2015; Anderson et al., 2016). Suboptimal loading patterns may therefore be observed for players who are either substitutes or simply are not involved in the game at all. As such, when a substitute player is required to play, their physical loading often exceeds the average distance an athlete travels per minute (relative TD) and starting players HSR. However, in contrast they consistently experience lower absolute match-play demands in comparison to players who complete a full 90-minute period (Barrett et al., 2019). Their reduced playing time may also restrict a substitutes opportunity to attain the peak HSR, SPR and perhaps more importantly metabolic responses of their whole match playing counterparts. These players often come within the

'fringe' player category as described by Anderson et al., (2016) playing between 30 – 60 % of available match minutes. Due to their physical loading pattern, rationale could be provided to suggest that players within this category are potentially being exposed least to the various important physiological stimuli. One explanation of this hypothesis could be due to their sub-optimal participation in match play but then also a smaller 'top up' session due to playing partial match minutes. Furthermore, there is another practical paradox for fringe players. They cannot be trained excessively more than starters in the training leading up to a game (particularly MD-1 and MD-2) in case they need to come off the bench and play. For example, a starting player might get injured in the first minute, which means the fringe player essentially has to play 90 mins (although rare), same for if players are sent off to change the tactical requirements and physical demands. In addition, non-playing players do not usually complete a high volume or intensity of work on a MD-1 or MD-2. Substitutes, who do not participate within the match at all, do however often complete a longer top up session post game, although this still has some time constraints due to logistical reasons, or a full training session the day after the match.

The overriding problem with programming loading patterns in elite soccer is that players cannot simply be exposed to more training or longer training sessions leading up to the match. This is because they might have to participate in the game and therefore their physical preparation may lead to overreaching (exposure to more than a player is capable of recovering from). There are practical difficulties to which this commentary will aim to provide recommendations to help solve these issues. For instance, running after the match may not be sufficient to provide the required stimuli and a session the day after the game might be impractical. As such, based on the scientific rationale and justification for all players needing to be physically prepared to participate in competitive soccer matches, this commentary aims to summarize the current evidence regarding this topic and inform evidence-based implementation within both the research and applied settings. It is divided into six sections: 1) Evidence-based training load methodologies for maintaining and developing squad fitness; 2) How to keep players 'ready to play' who are not involved regularly within competitive match play; 3) How should interventions be implemented to close the gap between players who receive varied accumulative physical loads?; 4) What other methods could fitness coaches

implement to allow for development/maintenance of fitness of players who are regular non-starters?; 5) Recommendations for effective implementation of top ups and post-match conditioning to prepare all players from a physical standpoint in applied soccer settings; 6) Limitations and future directions

Section 2 - Evidence-based training load methodologies for maintaining and developing squad fitness

When considering the current literature on maintaining whole squad fitness in preparation for match play, it seems evident that there is not yet a consensus as to the best methods or strategies to achieve this. Some practitioners may deem external based training volume (total distance or time spent training) to be of vast importance to match performance across the squad, where others may believe matching internal load (HR based measures such as HR exertion) across the squad is imperative to maintain and develop squad fitness, although within the current literature it seems like there is a large focus on the external load measures at present. Some may choose a combination of both. Regardless, understanding which day in the week is best suited to implement additional conditioning sessions is the first paradigm to consider. Once this has been determined then the specific physical measures (internal and external) that a fitness coach may choose to monitor can then follow.

Technology has been developed in order to understand both the internal and external training load a player has been exposed to. The technology which is used to monitor training load is an important point of note and as a practitioner, a good understanding of the devices which are used to track data is required. These devices are not without a variety of short comings. These can be issues such as simply having the appropriate equipment, to its validity, all which are important aspects to understand before its use. The evolution of technological devices (e.g. GPS, heart rate monitors HR, etc.) and the development and validation of new observational tactical instrument tools do however help coaches and scientists to study this specific tactical, physiological and biomechanical characteristics of different training. Understanding the physiological demands of training and match play is vital to allow for

appropriate training loads to be seen amongst the squad.

The findings of chapter 5 show that match participation is a large component of the microcycle in regard to physical stimuli it seems evident that an understanding of how match play demands can be replicated for players of sub-optimal participation is important. Previous research has aimed to understand the demands of match play in order to replicate the relative demands of the game by manipulating small sided games (SSG) in different ways to overload and elicit different physiological responses (Owen et al., 2004; Lacome et al., 2016). The main way in which SSGs are manipulated is by altering the m^2 per player. This means that the relative pitch space per player can be altered depending on the number of players within the session to allow for specific physical aspects to be overloaded. SSGs are widely used during soccer training and although there are many different designs (e.g. varying pitch sizes, number of players, etc.) there is a lack of consistency between previous studies which have examined such aspects. This makes it difficult to compare the results from specific groups of players (varying ages and quality level). Research has provided evidence that the primary benefits of SSGs are that they replicate the movement demands, physiological intensity, and technical requirements of competitive match play (Gregson et al., 2010; Little, 2009). Assessing the acute effects of the number of players within the SSG continuum has been prevalent with findings suggesting that lower player numbers (i.e. 1 vs. 1 to 4 vs. 4 small-sided) significantly increases the physiological demand compared to medium-sided games (5 vs. 5 to 8 vs. 8) or large-sided games (> 9 vs. 9) (Katis & Kellis, 2009; Little & Williams, 2007; Owen et al., 2011). These findings suggest that heart rate, blood lactate concentrations and RPE are higher between ~ 90%HRmax during extreme-sided games to 85%HRmax during SSGs, with a progressive decrease to 81%HRmax in large-sided games (Dellal et al., 2011; Little & Williams, 2007). It should be highlighted that 1 v 1 to 4 v 4 SSGs seem to be generally played at a higher intensity than large sided games. This therefore focuses training on the glycolytic system in turn improving anaerobic capacity. In contrast, an increase in the number of players will decrease the physiological intensity but allow for increased technical and tactical development. Coaches therefore should choose the appropriate size of games in accordance with the main goal of the top up or conditioning training session (Dellal et al.,

2011). As such, practitioners often prescribe different manipulations on these small sided games; for instance, larger relative pitch side per player, a floater player (i.e. players who support both teams in offensive phases of the game, Hills et al., 2020) or offsides (if any part of the body of feet is nearer to the opponents goal line than both the ball and the last opponent) to overload either the external or internal demands. These small sided games along with traditional high-intensity interval training (HIIT) based methods (Bucheit and Laursen, 2013) often make up the bulk of physical training prescription within soccer training sessions. Recommendations of when these SSGs can be implemented for fringe and non-starting players may be at the end of the MD +1 or MD +2 training session whereby the starters have finished their training/recovery for the day. Perhaps another method, possibly more likely is when the starters are not involved in MD +1 or MD +2 sessions, or when a one game a week microcycle is observed on a MD-4 or MD-3, the SSG can make up the majority of the training session whilst the starting players are on recovery. Overall the key message is that the manipulation of the pitch size of the small sided game is key to obtain specific physical output of the session (i.e. larger pitch = more high speed distance) which is the predominant stimulus that players miss when they miss a match day. The issue then becomes then about the number of players that are available to do top ups/extra training sessions as when starters are removed there are very few players remaining (<10 players typically). Practically it is much harder to do a 5v5 on a larger pitch.

With soccer training methodologies evolving using the principles of HIT training and match derived situations; integrated types of physical training have become much more common, such as the use of SSG described in the previous section. Lacome et al., (2016) aimed to compare the peak intensity of SSG with those of official matches in terms of running demands and mechanical work completed. An understanding of which could aid in the decision making for recommendations of specific and individualised training prescriptions for players involved within these top up, conditioning based sessions. Peak intensity periods can be modulated during the SSG with varying format and/or durations to overload or underload specific match demands that players have not been exposed to (Lacome et al, 2016). 4v4 was found to be optimal for overloading mechanical load and HSR demands in comparison with match play

with suggestions that for substitutes, the day after the match, similar external load exposure should be administered to that of those players who regularly participate within match play. Caution should still be observed with solely analysing peak intensity, as it is usually the accumulated training load which is more important in regard to maintaining and enhancing fitness Another common method that is widely used within soccer to increase physiological capacity is isolated running drills. Over many years it has been commonplace that long duration continuous running has been implemented by practitioners to increase metabolic fitness. However, previous research (Buchheit and Laursen, 2003) illustrated the requirement for more targeted specific training. They have developed a continuum of high-intensity training (HIT) based methods, which alongside the longer duration continuous work give practitioners the tools to provide specificity of training. In relation to top ups and conditioning sessions, as each player will require a slightly different stimulus due to their status′ regarding physical preparation and readiness, having individualised methods seems of benefit to prescribe training.

The use of HIT training by definition "involves repeated short-to-long bouts of high-intensity exercise interspersed with recovery periods'' (Billat et al., 2001). HIT protocols that elicit maximal oxygen uptake or a higher percentage of VO_{2max}, stress the oxygen transport and utilization systems which provide enough of a stimulus for enhancing VO_{2max} capacity (Laursen and Jenkins, 2002). To prescribe HIT and ensure that athletes reach the required intensity, several approaches exist. These aim to control and individualize exercise speed and use approaches such as heart rate-based prescription, rating of perceived exertion (RPE) based prescription, or anaerobic speed reserve/peak speed reached in 30-15 intermittent endurance test. The responses to variations of interval training should also be taken into consideration when planning interventions; maximising time spent at VO_{2max} and cardiac response with HIT and repeated sprint efforts. For instance, an example found in Lacome et al., (2016) used a game-based running HIT derivative, which was 15s at MAS with 15s passive recovery for 6 mins for the specific response they intended to achieve. This response allowed for an overload of maximal aerobic speed and in turn developed their aerobic system. In relation to the approaches to overload HIT training, at least seven variables can be

manipulated to prescribe different HIT sessions (Buchheit and Laursen, 2013).

Table 6.1 High Intensity training variables adapted from Buchheit and Laursen, 2013.

(1) Intensity of work intervals
(2) Duration of work intervals
(3) Duration of rest intervals
(4) Intensity of rest interval – passive (no activity) or active (low intensity activity)
(5) Number of work-to-rest intervals
(6) Number of series
(7) Exercise selection

The intensity and duration of work and relief intervals are the key influencing factors (Astrand et al., 1960), along with the number of intervals, the number of series and between-series recovery durations and intensities on the total work performed. Understanding how SSGs and HIT principles can be manipulated to enhance and target specific physiological responses is required for individual prescription of top ups and conditioning sessions. The aim of each 'conditioned' session is to overload the desired fitness component relative to the match demands that a player has not achieved. For example, during an "endurance-targeted session", parallel to a high metabolic load, coaches generally aim for a relatively high average running pace (meters per minute) and large activity volumes. Therefore, from a pure locomotor standpoint, the 4v4, 6v6 and to a lesser extent the 8v8 might not allow overloading the running loads of endurance-oriented sessions (Lacome et al., 2016). This may be seen within the 10v10 format which is more likely the optimal format to program submaximal endurance-oriented sessions. In relation to top up and conditioning sessions though, 10v10 is likely to be impossible to implement with players who are not involved in matches. As a key aspect of this commentary is to provide suggestions as to what coaches can do better to recreate and represent the stimulus that non-playing squad has missed, the following sections will aim to address this.

How do we keep players 'ready to play' who are not involved regularly within competitive match play?

Literature suggests that training sessions within a periodized micro-cycle may fail to deliver match equivalent load measures such as TD, HSR and metabolic load (Morgans et al., 2018; Gualteri et al., 2020). Soccer conditioning coaches should look to individualise different training methods to ensure that players are adequately conditioned in preparation for potential match play, considering individual players' match time exposure (e.g. starters vs non -starters) for an effective management of their load. As mentioned previously in this commentary, they cannot simply be exposed to more training throughout the training week as they potentially may be required for match play at the end of the given week. In addition, during dense fixture periods where training time is limited, creative ways are required to allow for implementation of top up sessions for non-starters immediately after the match conclusion (Gualteri et al., 2020). This may differ slightly at youth level, for example U16 and U16 squads within academies may only be involved in one game per week due to lower involvement in competitions in comparison with first team soccer, however there will still be dense fixture periods across the season (e.g. youth tournaments). The primary focus of 'topping-up' is to ensure that non-starters do not receive acute deficits in match-play stimulus (Anderson et al., 2016). In addition, the data may indicate that there is an importance of considering a players physical loading from an overall training cycle perspective. It is therefore the skill of the practitioner to make appropriate decisions around the prescription for each individual player's requirements. Therefore, an understanding is necessary in relation to how it is best to implement measures to close the gap between starters and non-starters in relation to their training load and more so their potential fitness changes and physical readiness.

How should an intervention be implemented to close the gap between players who receive varied accumulative physical load?

As it is evident that the match will be a large contributor to an individual's physical load across a microcycle, it further highlights the importance of top up conditioning sessions, either post-match or the preceding day. Team-based training sessions are usually designed around the premise that the match is a heavily weighted contributor to players' physical load and therefore players who are not involved may experience a decline in relation to sport-specific physical performance adaptations. In addition, they may be put at greater risk of sustaining non-contact soft tissue injury. Recent studies have used performance data in the form of the most intense match-play periods to configure soccer-specific high-intensity training drills, to replicate the technical and tactical demands of the match, but in addition, encompassing physical training within the drill (Bucheit et al., 2013; Ade et al., 2014). Using this method would not only allow for players to achieve the external load measures that the sport science practitioner deems important, but also allow for technical coaches to focus on technical and tactical elements of the game. This will allow for increased player 'buy in' as a technical coach can lead the session, but it will also allow for replication of the contextual demands of the game that they have missed from match play to be provided from a physical perspective. This may not however be feasible, for example, at an away fixture where there are other factors might influence the ability for a SSG to be provided. In this instance, it seems practical for sport scientists to deliver an isolated running-based conditioning session to give some form of stimulus to the players. Where it is possible though, the day after a game and with a technical coach involved, ball-based drills and SSG seem useful as a conditioning tool for a multitude of reasons.

SSGs that are typically employed by practitioners throughout the week are useful as a top up session conditioning method to prepare players to cope with the demands that they have missed from lack of match play (Lacome et al., 2018). Hills et al., (2020), found top-ups elicited ~400m of HSR and ~30m of SPR, absolute values which may represent between 25-50 % (depending on position) of the demands typically experienced by outfield players who complete 90 min of match-play. These figures suggest that top ups may not completely solve discrepancies in physical load but may go some way to closing the gap. Data such as above may be indicative of a typical post-match running conditioning session, which are usually

provided due to the lack of available time and resources to provide a full training session. Where possible though, or the day after a game a more structured and focused session should be provided with the aid of coaches to help players develop physically by using a combination of SSG and HIT based training (Lacome et al., 2018; Bucheit et al., 2018).

In relation to SSG, playing rules, playing area, number of players, players' density, inclusion or exclusion of goalkeepers and work:rest ratios are all key aspects to consider. Each provides a slightly different physiological response with the aim to induce specific locomotor demands. (Lacome et al, 2018). When formatting the aforementioned rules correctly, SSGs can be associated with high occurrences of player interactions and have the ability to overload specific and targeted physical demands. Lacome et al., (2017) aimed to compare the peak intensity of typical SSGs with those of official matches in terms of running demands and mechanical work over different rolling average durations and playing positions. The findings of this research suggested that compared with matches, only 10v10 SSGs (102x67m pitch size) allowed players to reach similar running intensities (TD and HS), whereas 4v4 (25x30m; over 1 -4 min) allowed the attainment of a moderately-to-largely greater mechanical work intensity irrespective of the rolling average durations. It is highly doubtful that the day after a match there will be enough players available, as the majority of the squad would be on a recovery-based day to complete games any larger than 4 v 4. This means that a useful strategy could be using a combination of both SSG and isolated running drills to allow for all physiological aspects to be targeted. For instance, mechanical workload intensity was likely-to-most likely be higher during 4v4 than during matches for short-duration rolling averages. As this physiological response seems to be easily overloaded within SSG the issue now becomes how to get the metabolic/endurance-based responses that are seen within the match that these players are missing. One way is to use HIT based methods, which is detailed in the information in the previous section surrounding the scientific rationale, methodological framework and practical applications of high intensity running training for both individual and team-sport athletes (Buchheit and Laursen, 2018). Furthermore, running based derivates which attempt to attain a certain number of minutes at specific HR training zones may also be pertinent in obtaining physiological responses required for development.

An example of what a full training session may look like in regard to both external and internal load can be seen in Figure 6.2. Using an activity trace such as below allows for the practitioner to understand which specific drills elicited the responses that they deemed important to allow for alterations to be made for future reference if necessary. The figure also gives feedback for the effectiveness of the given practice to attempt to provide the adequate stimuli which was required. In addition, Figure 6.3 is another example screengrab of a HR trace similar to figure 6.2, however it a technical based MD-2 session.

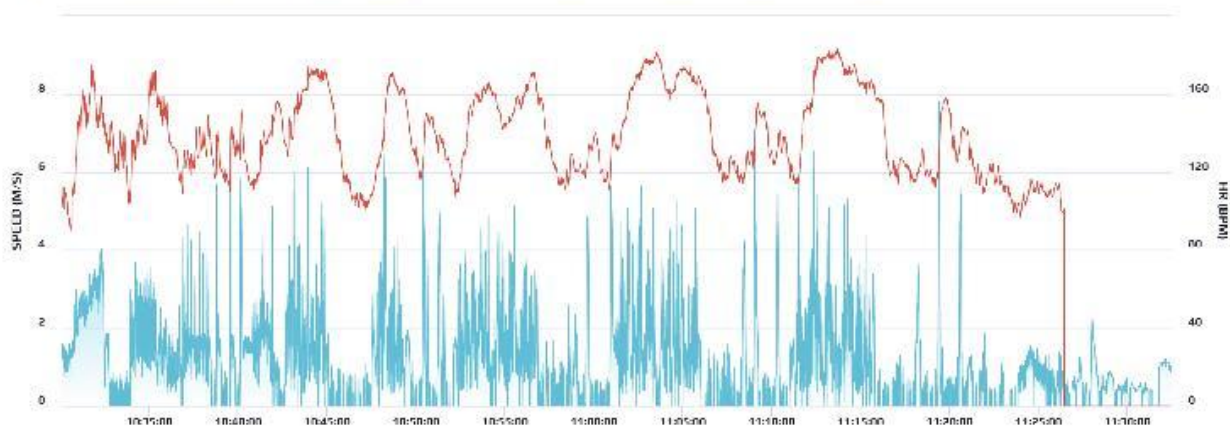

Figure 6.2 Activity graphs showing the speed profile of a typical MD-3 group training session along with Heart rate and sprints. Speed profile is represented by a blue line with the Heart Rate trace by the red line. Silingardi, S. 2020. Activity Trace (StatSports) https://statsports.com/

Figure 6.2 is a typical activity trace from a MD-3 training session at an elite category one English Premier League academy. The content of this specific session was as follows; warm Up, 3 team SSG (6v6+6 20x30m pitch), finishing in pairs, repeat full session 4 times. The HR trace demonstrates the internal stress that is placed upon the player, with it 'spiking' during activity and then dropping during the recovery period. Across the session the trend in HR rises suggesting that the session difficulty increased as the session progressed.

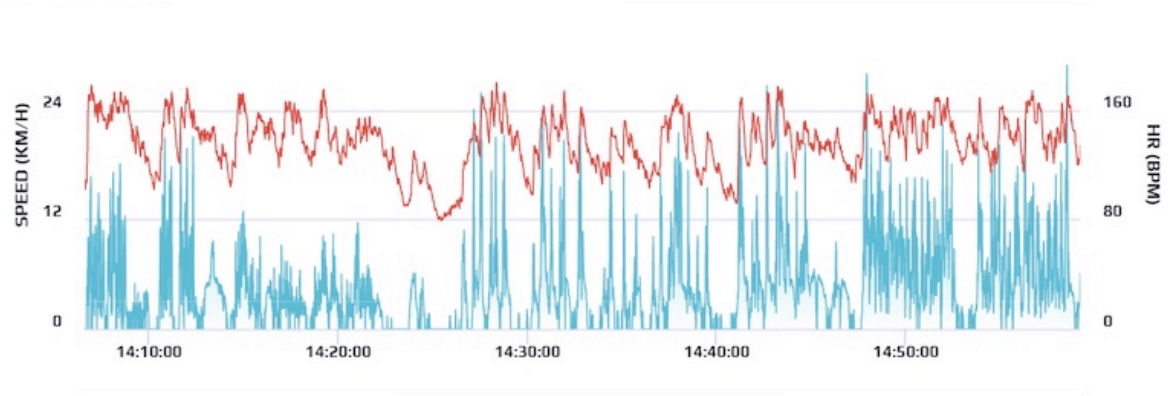

Figure 6.3 Activity graphs showing the speed profile of a typical MD-2 group training session along with Heart rate and sprints. Speed profile is represented by a blue line with the Heart Rate trace by the red line. Silingardi, S. 2020. Activity Trace (StatSports) https://statsports.com/

The activity graphs which are displayed in figures 6.2 and 6.3 is an example of HR traces of different training sessions (MD-3 and MD-2). They represent an acute bout of exercise, with the activity trace which is the blue lines on the graph showing the external load (speed trace) which has elicited the specific internal response shown by the red line. An understanding of the type of HR responses which specific sessions elicit is important for top up and conditioning sessions, however it should be noted that these traces are merely one session and therefore understanding the load from a more chronic perspective is required to ascertain the specific periodisation of a players training and match exposure in relation to physical markers.

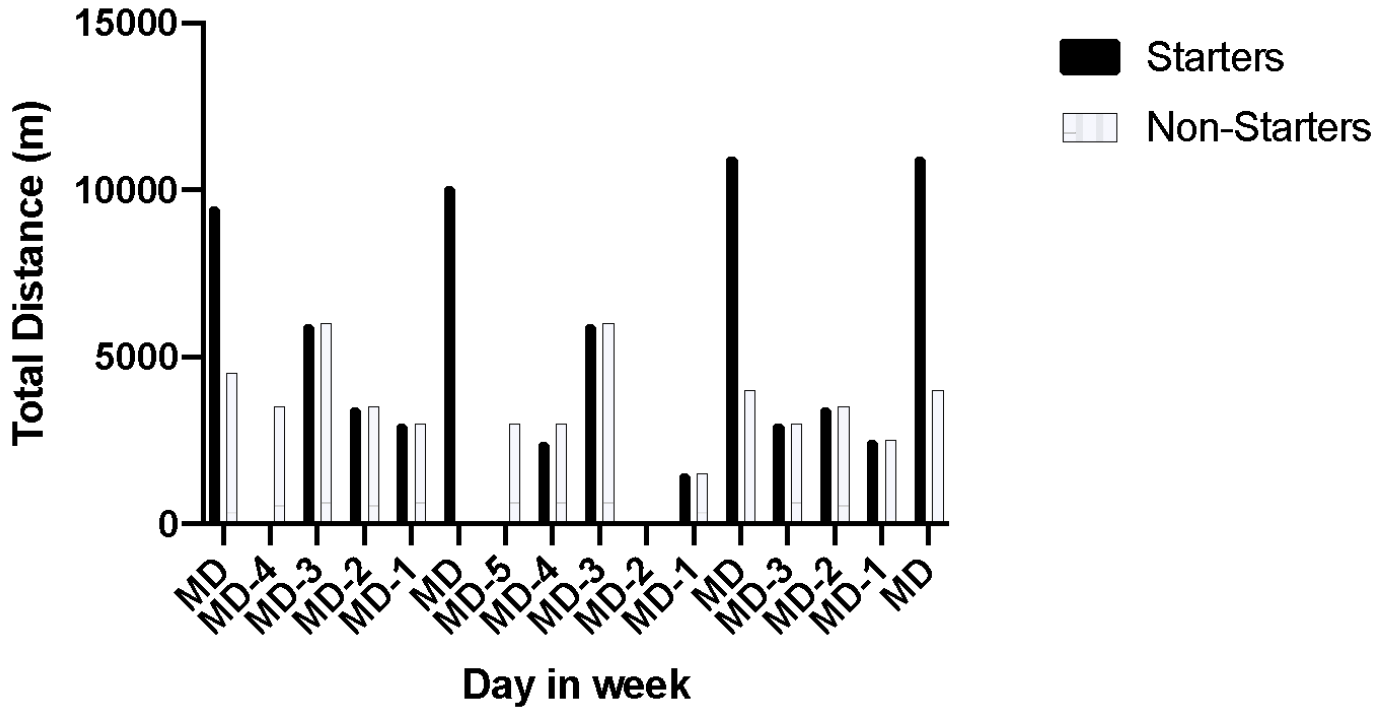

Figure 6.4. Distribution of Total Distance for typical starting and non-starting players.

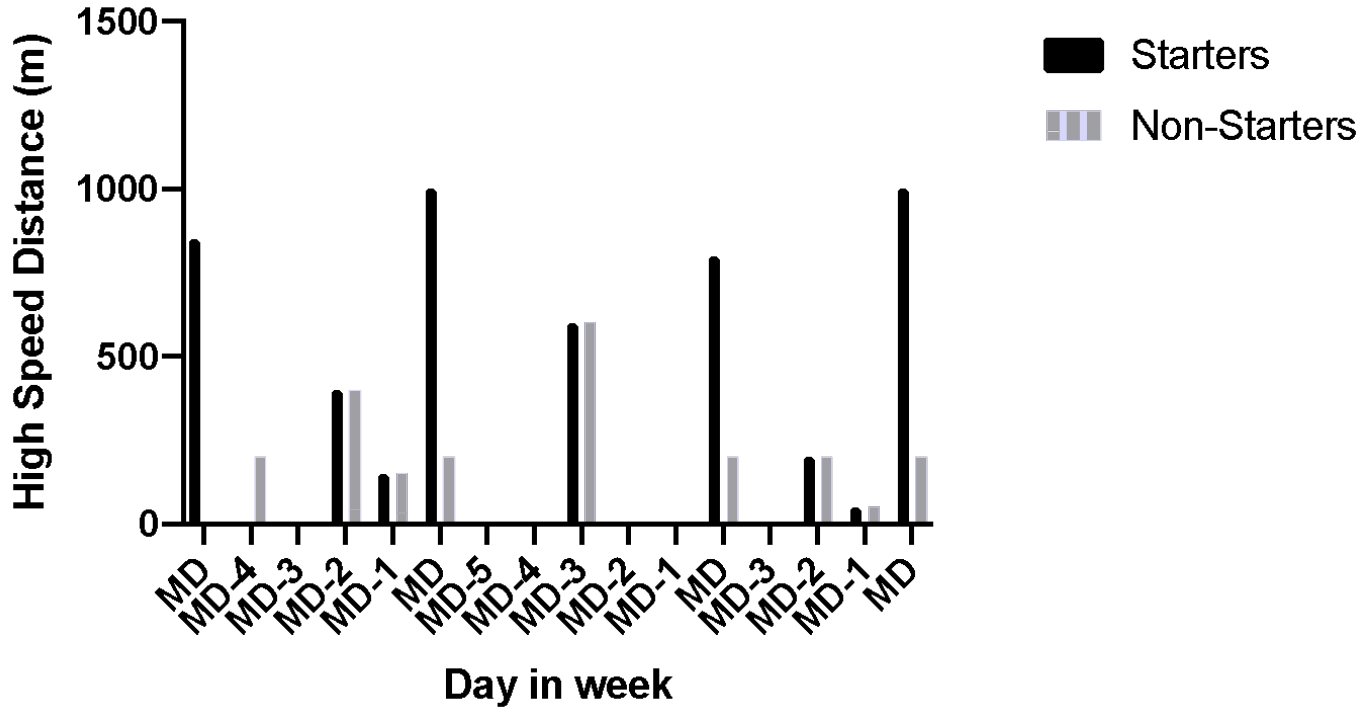

Figure 6.5. Distribution of High Speed running for typical starting and non-starting players.

Figures 6.4 and 6.5 provide examples of the physical loading (TD and HSR) which typical starters and non-starters within a squad might be exposed to. It is clear that players who fall within starters category achieve a large proportion of their total distance and HSR through match play. In contrast a typical non-starter does not, with further suggestions with the data providing an insight into the monotonous nature of training sessions without match play. These players participate in a large number of training sessions, with little match exposure, with figures demonstrating the differences between players' status in relation to how their physiological loading is administered to them. It also demonstrates how a lack of match exposure may affect non-starters from a chronic perspective.

What other methods could fitness coaches implement to allow for development/maintenance of fitness of players who are regular non-starters?

There is current literature which uses intervention-based approaches in different sports which have attempted to overload and develop a specific aspect of physiological development. However, at present there is little research of this kind in elite soccer. The use of this methodology has the potential to be used and applied within soccer, to effectively explore the effects of specific running-based or SSG-based training to improve physical qualities within soccer players. Recent research in rugby has attempted to do this, where a 2-week intervention which involved 6 sessions with each session including 6 (week 1) or 8 (week 2) 30- second repetitions of maximal shuttle sprinting (Dobbin et al. 2019). Findings demonstrated that from a between group perspective submaximal internal and external responses to training indicated that both interventions were very high-intensity training modalities; rugby specific sprint interval training (SIT) elicited a greater metabolic load, whereas the running specific SIT group covered greater distance at a higher mean speed. Two weeks of both SIT rugby and SIT running interventions were effective for eliciting positive changes in the physical characteristics, heart rate recovery (HRR), and the submaximal responses to the Yo-Yo IR1 with few clear differences in the SD of the individual responses. The findings should encourage practitioners to consider including sport-specific, metabolically demanding actions in any given sport. The results also revealed that incorporating SIT training within the competitive season is feasible without compromising athlete wellbeing or neuromuscular function and therefore should be considered by practitioners. This study represents the potential that specific interventions in season, which could be used for 'topping up' and conditioning sessions, can be implemented to try and elicit development of a specific physiological component without detriment to match play. One issue which may be evident from this type of intervention is that although by doing these 'micro doses' of exercise, they will elicit endurance adaptations, if a player if then asked to perform 1000m high-speed running for several games in quick succession, will this type of intervention ultimately prepare them for this. As such, it is clear that there is a trade-off between adaptation and load accumulation per se.

As match play in soccer is multidirectional in nature, players must be exposed to a multitude of physical stimuli to allow for optimal development. However, in relation to the extra top up sessions, it is important to note that not all physical qualities can be focussed on and developed in any one given session and therefore an understanding that the physical conditioning needs to be periodised accordingly is necessary. The top up sessions can however be used effectively as a development opportunity for specific physical work to be delivered to a player who may be lacking in one area as a result of limited match exposure. We know that the physical demands a match provides an individual has a key role for the overall volume and intensity that an individual is typically exposed to. Therefore, these additional sessions may not replicate the equivalent loading from either an external or metabolic perspective however they can go part way to helping the process. For instance, a player may require to be topped up from an internal metabolic perspective running based drills which limit the HSR and SPR exposure. In contrast, another individual, due to lack of HSR and sprinting exposure might require a different physiological stimulus. One potential method to improve a non-starters training exposure, is to implement friendly matches, either with other clubs, or in house matches against players from younger age groups or a mixture of junior and senior players. These matches are often much less intense than the competitive matches themselves (Castellano et al., 2013), however, may provide sport specific movements and an increase in the training exposure in comparison to SSG and running alone.

Recommendations for effective implementation of top ups and post-match conditioning to prepare all players from a physical standpoint in applied soccer settings

As a result of the scientific background and contemporary literature the following evidenced-based recommendations can be provided:

- Large SSGs 10v10 would be optimal to allow for a moderate overload in the intensity of match locomotor demands (TD and HS). However, due to lack of players that are available for top up sessions, it may be more useful to use a combination of small SSG

(eg, 4v4) and HIT training to elicit the desired responses.

- Appropriate tracking systems such as heart rate and GPS should be used to monitor training load. This will allow for a comprehensive understanding of the total exposure players have achieved been subjected to.
- Individualization of the top up session is key. This should be based upon what the player has achieved in relation to exposure to each training variable throughout the previous week. Where a player has not received adequate stimuli, this should be the main focus of the session.
- Periodization of the training should be based on starting status (e.g. starters and non-starters) and match position demands in order to optimize recovery and performance for match-day.
- Medium and large sized (>165m ^{2} per player) SSG can be used to ensure HSR and SPR exposure demands are met, with smaller sized SSG allowing for mechanical adaptations.
- Although linear based isolated running drills may be preferable methods for hitting external workload measures, due to efficiency of delivery, game-based drills allow for replication of sport specific movement patterns to be met.

Limitations and future directions

From the existing literature the following limitations and future research questions emerge:

- When implementing top up sessions immediately after a match, contextual variables, such as substitution timing, match location, result of match, time of day, fixture density and the psychological morale of the players should be considered. Practitioners should consider all barriers, practical and logistical when designing specific match day top up sessions.
- When implementing conditioning training sessions, the day after the match, the number of players available will be key in determining the content of the session. Practitioners should understand how manipulating SSG variables such as pitch size

and duration affect mechanical, metabolic and acute physiological responses.

- In relation to individualisation of the training load, periodization principles should be understood by the practitioner. This will allow for specific player requirements to be focused upon within the conditioning/top up session, allowing for appropriate volume, frequency and density to be achieved. A blanket squad-based approach cannot simply be used, every player needs individual consideration.
- Players cannot simply participate in extra training throughout the training week leading up to a match, due to their potential requirement to play in the match at the weekend. As such innovative methods of top ups and conditioning need to be implemented.

- Further studies need to investigate relationships between additional conditioning sessions and their prescriptions contributing to the increased player availability for match play when required. In addition, limited evidence exists regarding management of players physiological status during the weekly microcycle maintains or develops physical qualities to allow for optimal match play performance and should be further researched.

Conclusions

It is clear that individualisation of players' training load is required for optimal physical development within a squad setting due to the variation in match stimuli experienced by different individuals. This commentary has summarised the scientific rationale, current literature and practical recommendations to maintain and develop physical fitness in professional soccer. The literature allows for methodological guidelines for coaches and practitioners to use, although future research is required to advance the practices which aim to optimise physical fitness to help negate the negative adaptations seen with low match exposure.

CHAPTER SEVEN

SYNTHESIS OF FINDINGS

SYNTHESIS OF FINDINGS

The purpose of this following chapter is to consider the findings of this thesis in regard to the original aim and subsequent objectives of the research program. Practical recommendations to optimise training processes in relation to long term elite youth soccer training programs will be discussed based upon the synthesis of the major findings. Limitations and future recommendations for future research based on the findings will also be examined.

REALISATION OF AIMS AND OBJECTIVES

The primary aim of this thesis was to evaluate the relative importance of physical development strategies to successful performance in elite youth soccer. This was met through the completion of four separate studies (Chapter 3, 4, 5 and 6) investigating the following objectives:

Objective 1: Understand the perspective of key stakeholders in the development process (i.e. coaches) towards the importance of physical development to the success of elite youth soccer players

To fully understand the training load and physical development, which was evaluated in chapter 5, first it seemed important to understand key stakeholders′ perspectives on the relative importance of physical development in elite youth soccer players. Following this, a more thorough understanding of the training load, and perhaps differences in match involvement in the squad may be explained in more detail. To achieve objective 1 though, a qualitative interview was conducted at an English premier league (category 1) academy whereby fitness coaches, technical coaches and an academy director were asked questions in an attempt to understand the training approaches in place and the rationale behind them. Specifically, there was an attempt to understand this in relation to the physical aspect of the program. This then allowed for an understanding of the coaches′ perspectives on the relative importance of physical development to be observed within the overall development program. The findings of the chapter 3 showed that elite coaches deemed the physical

development of players as a key aspect of player development, with the aim of this current academy in question to prepare players for their first team squad. In addition, coaches were keen to stress that improvements in physical performance would allow players to spend more time training due to less injury, therefore increased opportunities to learn and develop as a player. Another important point that was raised was that match involvement was a key part of a player's development, however winning matches within this academy setting was not. As such coaches suggested that the match was merely an extension of the training schedule. The findings of this study allowed us to provide context and an insight into the training load and change in physical fitness that was observed in chapter 5.

Objective 2: Identify physical tests that have potential to be sensitive to identify changes in physical fitness and to understand the relationship of measures of internal and external training load with test outcome

In order to monitor the training load before evaluating its effectiveness in relation to the development of physical performance markers across a season, it was first important to evaluate the current research that is within the literature to suggest appropriate methods to administer within chapter 5. As such, a systematic review was conducted in chapter 4 to meet this objective. The review indicated that tests such as a maximal aerobic speed (MAS) test, YoYo Intermittent test derivatives and laboratory based incremental running tests seem to be sensitive enough to detect aerobic and anaerobic capacity changes across respective training periods. However, following this review it was evident that there is limited evidence in youth soccer that accurately monitors TL in relation to physical development longitudinally. Therefore, further research was required (chapter 5) in order to understand the best methods to track and monitor physical performance across a season, also in relation to the involvement in match play.

Objective 3: To evaluate the role of match-play in changes in the physical performance of elite youth soccer players across a competitive season

Considering the outcomes of both chapters 3 and 4, a longitudinal tracking study was conducted to quantify the accumulative training and match load across an annual season in elite academy soccer. In doing so, its effectiveness in relation to the development of physical performance across this time frame could be observed. Furthermore, this research also aimed to understand how training influences athlete performance and the specific key parameters which may provide correlations to allow for an understanding between training load and changes in fitness with the submaximal YoYo IE2 fitness test across an elite youth soccer season. In addition, an understanding of how much of the physical stimulus comes from the training prescription and how much comes from matches in periods two, four and six weeks prior to the physical testing period. The key finding of this study was that when the starting status was accounted for in relation to the examination of aerobic fitness, Starters had a consistently lower HR in the submax YoYo IE2 across the season (apart from E1). It was evident that there were moderate correlations with number of matches played, total duration of training, total distance performed and total high-speed running between tests, with the strength of the correlation increasing in correlation with a higher chronic load from the individual. At six weeks the correlations were strongest; Number of Matches Played (-0.33), Total Duration of Training (-0.45), Total Distance Performed (-0.51), and Total High-Speed Running (-0.42), SPR (-0.32) and total a/ds (-0.4) were found. This suggests that the more training and match involvement a player is exposed to, the lower the players maximum HR in the test. The findings of our study also demonstrate that there are significant differences in physical fitness when involved consistently in match play.

Objective 4: To provide evidence-based training load methodologies for maintaining and developing squad fitness and in addition provide recommendations on how to keep players 'ready to play' who are not involved regularly within competitive match play.

The objective was met in chapter 6. Information gathered in chapter 5 was analysed and it was evident that recommendations were required to provide information as to 'how to close the gap' between players who play regularly in matches with those who do not in terms of physical stimuli differences. Therefore, the aim of chapter 6 was to provide a commentary which summarises the scientific rationale, current literature and practical recommendations

to maintain and develop physical fitness in professional soccer. The initial aim was to provide an intervention piece as described in the prologue of chapter 6 but due to the worldwide pandemic in 2020 this was halted. Instead, this commentary was designed to provide preliminary methodological guidelines for coaches and practitioners to use. The recommendations include: Individual periodization of training should be based on starting status (e.g. starters or non-starters) and match position demands in order to optimize recovery, match-day performance and overall physical development. Practitioners should understand how manipulating SSG variables such as pitch size and duration affect mechanical, metabolic and acute physiological responses to allow for appropriate top up protocols to be implemented. In relation to designing top up sessions, medium and large SSG can be used to ensure HSR and SPR exposure demands are met, with smaller SSG allowing for mechanical based adaptations. Isolated running drills may also be used within conditioning sessions to provide appropriate conditioning stimuli.

GENERAL DISCUSSION

This research programme investigated the relative importance of physical development strategies employed in elite youth soccer. Furthermore, it attempted to understand key stakeholders′ perspectives on the importance of physical development, before making recommendations as to how to implement training for players who may receive inadequate exposure. To our knowledge it was the first research project to evaluate physical development over the course of the season in relation to the systematic involvement in match play in elite youth soccer. This should be considered as a key finding, as we believe that when players are involved within a development program, such as academies, that they should all be given a fair chance in relation to developing from a physical perspective.

The ability for a player to develop from a physical perspective within youth soccer is highly dependent on the programmes and the coaches which deliver them. It is clear that the actions of coaches significantly impact on the behaviours, cognitions, and affective responses of players, influencing also whether and what they learn and achieve (Cushion, 2012). Individual coach behaviours then reflect their beliefs that usually come from previous experiences.

However, within a developmental model it seems necessary that all coaches have a concurrent philosophy that drives the same message. Prior to this research program there was little research into the coaches′ values, beliefs and attitudes alongside their overall philosophies with respect to the relative importance of the physical development of youth soccer players compared to development of tactical and technical abilities (Suzuki et al., 2006). An understanding of the beforementioned was required to understand the rationale behind some of the training approaches in place at elite youth soccer academies along with perspectives of key stakeholders′ opinions on the relative importance on physical development within the development of the athlete is therefore required. This also allowed for an understanding as to the identification and talent development programmes that are implemented within elite youth soccer. The information provided also gave insights as to these stakeholder′s ideas surrounding the importance of match play in youth soccer with the conclusions providing a platform for more appropriate holistic players development programmes to be planned and implemented.

The findings of chapter 3 also showed how elite coaches deemed the relative importance of physical development. Coaches, both technical and physical, believed that the importance of physical development within elite youth soccer is very important, albeit it that different factors have different influences upon this. Moreover, it should be noted that a key point that arose from this study was that having a clear structure in place within the club, allowing for all staff and players to have a comprehensive understanding of what the main goals of the development process, is key for the overall success. For example, if a staff member leaves, then a new member could come in and be embedded in a process which would see the overall ideas of the academy to be continued to be relayed in practice. Therefore, evidence and coaches′ beliefs corroborate that physical development, and having an integrated staff approach is of utmost importance. Naturally, the main objective of the academy process is to get a youth player into the first team, and that strategies, including physical ones, should be implemented to get a favourable outcome. This study allowed us to confirm and provide new insights into the different approaches in previous research used for physical development within elite youth soccer, with the next study able to understand how physical development is implemented in this club from a quantitative standpoint. Given the expertise of the coaches

that were interviewed, soccer practitioners could consider the findings useful for a better understanding of the methods of physical development integration in a holistic program. This study does have some limitations that should be notes. Although the coaches interviewed within this study were from an elite category one English premier league academy, it only represents one club's philosophy. A further understanding in the future of other clubs' ideas around the relative importance would allow a cross comparison of physical development in youth soccer to evolve.

In terms of chapter 4, the review in this research program was the first to provide a systematic evaluation of the association between training load and physical development using the current literature available within elite youth soccer. There were positive relationships observed between external training load/total exposure (training and games) along with HR based variables with changes in aerobic performance. This suggests that increased training exposure, and perhaps more specifically increased training at a higher percentage of maximum heart rate may be indicative of increased performance capabilities. These outcomes also seem to be in keeping with previous research that has illustrated that these performance tests are both valid and reliable in detecting changes in aerobic capacity (Schmitz et al., 2018). Furthermore, when attempting to understand the training load in soccer players, it seems important to consider the load from a wide array of physiological systems that are potentially affected by the given bout of exercise. For instance, following both training and match play, multiple physiological systems are taxed, and as such, the response to this given training stimulus may be specific to not only each of these systems but the player/individual themselves. With a good understanding of the training load that a player is exposed to, practitioners are able to consistently monitor and alter the responses of the circulatory system during soccer training to allow for specific and desired training responses to be adhered to. In order to accurately monitor and understand how this stimulus has affected a player's physical capacity, accurate and reliable tests are required. The findings of this review suggest that, from an aerobic capacity standpoint, field-based tests such as the aforementioned show good utility and may be used in youth soccer training programs.

In summary, it seems evident that there are a whole range of outcome variables that are derived from laboratory and field-based tests that use complex to simple equipment that can be used to detect changes in fitness that are related to aerobic fitness. Overall, it is evident that an increased exposure to training provides players with stimuli which may in turn improve players aerobic performance. In addition, there is some evidence to suggest that it may also be important to include a measure of intensity to objectively quantify an individual's stimulus to the training load, although no definitive conclusions can be made at this point. More detailed research is still required regarding external load measures to quantify the training load in relation to performance changes are required. Currently, only two articles (Gibson et al., 2018; Fitzpatrick et al., 2018) use GPS, with the remaining studies using total exposure. Where possible, the use of external load measures via GPS such as speed and distance should be monitored as mere exposure does not provide enough detail regarding the intensity and the demands of the given stimulus. It should be noted that the budgets within youth soccer to be able to finance the use of certain technology may be a limitation and ultimately limit the choices of methodology used at certain clubs. Finally, further research is required to provide a consensus on the best methods of tracking and monitor the changes within an elite sporting setting.

Following chapter 3, whereby coaches noted that physical development, and the involvement in match play was an important factor of players' development as a whole, it seemed sensible in chapter 5 to understand by quantifying the training and match load in the given academy to provide conclusions on the appropriateness of the given soccer training to prepare the players. It is well understood that the purpose of soccer training is to prepare the player from both a physical and tactical standpoint, and further to allow for a physical readiness for the demands of match play. Therefore, it should be understood that the response to a soccer training session or match will be specific to each individual player due to factors such as genetic background and previous training experience (Bouchard & Rankinen 2001). With this in mind, training programs need to be adjusted to suit the demands of each given individual player (Bompa 2009). As such, practitioners should ensure that training is structured in a way that not only allows for optimal training adaptation with regard to long term development, but also to allow for preparation of matches.

In chapter 3, coaches concluded that the match was just an extension of training, and that perhaps players could go into the match under slight fatigue, although were key to stress that overreaching and perhaps causing injury would not be recommended. In contrast though there is evidence to suggest that functional overreaching, whereby players are pushed to an appropriate level to develop physically may be important in this academy setting; especially when the goal is to drive adaptation in players to reach the first team. For instance, (Aubry et al, 2014; 2015) demonstrated that the supercompensation effect in functional overreaching was increased in comparison with acute and chronically fatigued athletes. Due to the high competition demands in academy soccer, across an annual cycle, coaches are required therefore to structure training to allow for both of the aforementioned to occur. One issue that is commonly observed however within category 1 academies is that players are often involved at international training camps and competitions. As such, this adds to the quantification issues and managing training load aspects on a chronic level. It is crucial that the correct individual training load is applied in context to the requirements of the soccer competitive cycle. For instance, our data in chapter 5 demonstrates that when the starting status of players was accounted for in relation to the examination of aerobic fitness; Starters had a consistently lower HR response to the submax YoYo IE2 than both fringe and non-starting players across the season (except E1). The aim of Chapter 5 of this thesis was to quantify the accumulative training and match load across an annual season of elite academy soccer, in order for its effectiveness in relation to the development of internal physical performance across this time frame to be examined. To further explore the causation to these findings, the second aim of this study was to understand how the training prior to the test influenced athlete test performance and to identify key training load measures which provided an understanding between training load and changes in fitness measured by the YoYo IE2 test across an elite youth soccer season. As such, the relationship between training load and fitness was examined at the following time points; 2 weeks, 4 weeks, 6 weeks and all of the training prior to the test.

As already observed in other intermittent team sports such as handball (Goristiaga et al., 2008), individual match playing time (IMPT) seems to influence players' fitness during season. In fact, according to our findings, players within the starting category from time point E2 to E3

there were improvements in physical fitness. This may suggest that match play elicits higher physical stimuli and therefore has a positive effect in developing aerobic performance capabilities (Wisloff et al., 2004). In addition, the observed relationship between match playing time and these changes in physical performance favours of players who are involved in high percentage of available match minutes suggests that elite youth soccer players have capabilities to both maintain and possibly increase aerobic fitness throughout the season, and that competition time may possibly contribute to influence certain physical characteristics of professional soccer players. In contrast, it seems that both fringe and non-starters require additional training exposure, except that of normal training to improve and develop these characteristics.

In terms of the physical test that was chosen to be used within this research it was a submaximal version of the YoYo IE2, and although this form of testing is not without limitations, for this research program we felt it was the most suitable to give us the appropriate information we required. For instance, it is very unlikely an elite soccer team would agree to perform a maximal fitness test during the competitive season as it will disrupt the training schedule and potentially increase the risk of injury. Therefore submaximal runs (such as the one used in this research) may be a plausible alternative from which physiological response data is analysed in addition to tri-axial loading from accelerometers that may indicate changes in movement strategies associated with fatigue (Buchheit et al., 2018; Fitzpatrick et al., 2019b).

The findings of Chapter 5 revealed there were moderate negative correlations with number of matches played, total duration of training, total distance performed and total high-speed running, with the strength of the negative correlation increasing the further away from the test (2 weeks < 4 weeks < 6 weeks). At six weeks the correlations were strongest; Number of Matches Played (-0.33), Total Duration of Training (-0.45), Total Distance Performed (-0.51), and Total High-Speed Running (-0.42), SPR (-0.32) and total a/ds (-0.4) were found. This evidence suggests that the more training a player completes the lower the players maximum HR in the test. Therefore, if the training load is inadequately periodised to elicit a supercompensation effect then the players will not enhance their physiological status. In addition, it was evident that for players who were consistently non-starters that they will

become maladapted to the training load and possibly engage in a state of detraining if they are not regularly 'topped up' with extra training. In addition, with previous research has displayed that match play may be an important stimulus in elite players (Morgans et al., 2018), it is evident that for outfield players, who play full matches, the match days represent the most physically demanding days within a micro cycle (Di Salvo et al., 2007). It was evident in this study that the increased number of matches prior to the test in which an individual is involved in, that there is a strong negative correlation suggesting it is a key factor in relation to the decrease in HR within the test.

An understanding of how the systematic involvement in match play affects the physical development of soccer players therefore was therefore analysed to understand how important this match play actually is as a component of the strategy to improve the physical status of the player. With elite youth soccer players being involved in anywhere up to three competitive matches per week during the season, depending on the period of fixtures and the number of competitions in which the team is involved in. The competitive demands of match play may impose strains to various physiological systems, one being the metabolic system (Mohr et al, 2003). The effects of a large quantity of games may therefore be for the fitness coach to manage the players physical fitness training load and recovery strategies to ensure maximal match performance, but in addition, for player who are not regularly involved in the squad, it is important to maintain their physical fitness somewhat also. The findings also demonstrate an increased average HR value in each model from 2 to 6 weeks, this indicates that the longer the individual goes with no training or games their % MHR begins, on average, to rise in the test. Perhaps some coaches believe that employing excessive training load during the in-season period, combined with congested fixture scheduling, may increase the risk of injury to key players. Therefore, it may be evident that soccer cannot follow certain elements of traditional training periodisation modelling due to the external demands and must adapt its own methodology specific to the sport.

The data generated from both chapter 3 and 5 of this research demonstrate the importance of regular match involvement to improving an elite academy soccer player both subjectively by key stakeholders, and objectively through the data collection. An understanding in chapter

6 was required to employ methods for players who perhaps do not receive adequate match playing time. It should be noted however that the training patterns in this thesis are a consequence as to the methodology of this specific club and that it is highly likely that each individual soccer team will have a separate training approach that is designed to prepare players for the style of play in which they are attempting to play. With this in mind, it may be evident that the findings of Chapter 3 and 5 cannot be applied universally across soccer teams with different individual requirements. Some teams may employ different training structures in comparison to that observed in Chapter 5. Differences in training drills may have a profound effect on the physiological response and overall training loading (Little & Williams 2006).

The final chapter in this thesis (chapter 6) summarised the scientific rationale, current literature and practical recommendations to maintain and develop physical fitness in professional soccer. It is clear that individualisation of players' training load is required for optimal physical development within a squad setting due to the variation in match stimuli experienced by different individuals. The literature allows for methodological guidelines for coaches and practitioners to use, although future research is required to advance the practices which aim to optimise physical fitness to help negate the negative adaptations seen with low match exposure. In doing so it attempted to provide suggestions as to how best close the gap between both starters, fringe and non-starters for players who receive inadequate loading patterns to develop physically. Some of the findings were as follows:

- Large SSGs 10v10 would be optimal to allow for a moderate overload in the intensity of match locomotor demands (TD and HS). However, due to lack of players that are available for top up sessions, it may be more useful to use a combination of small SSG (eg, 4v4) and HIT training to elicit the desired responses.
- Individualization of the top up session is key. This should be based upon what the player has achieved in relation to exposure to each training variable throughout the previous week. Where a player has not received adequate stimuli, this should be the main focus of the session.

- Periodization of the training should be based on starting status (e.g. starters and non-starters) and match position demands in order to optimize recovery and performance for match-day.
- Although linear based isolated running drills may be preferable methods for hitting external workload measures, due to efficiency of delivery, game-based drills allow for replication of sport specific movement patterns to be met.

Unfortunately, due to worldwide pandemic which occurred during this research project, we were unable to provide information to understand whether the measures described in chapter 6 were effective in practice. Further studies are required to investigate relationships between additional conditioning sessions and their prescriptions contributing to the increased player availability for match play when required. From our research we can suggest that when implementing top up sessions immediately after a match, contextual variables, such as substitution timing, match location, result of match, time of day, fixture density and the psychological morale of the players should be considered. Practitioners should consider all barriers, practical and logistical when designing specific match day top up sessions. In relation to individualisation of the training load, periodization principles should be understood by the practitioner. This will allow for specific player requirements to be focused upon within the conditioning/top up session, allowing for appropriate volume, frequency and density to be achieved. A blanket squad-based approach cannot simply be used, every player needs individual consideration. Players cannot simply participate in extra training throughout the training week leading up to a match, due to their potential requirement to play in the match at the weekend. As such innovative methods of top ups and conditioning need to be implemented. Regrettably this caused us to only be able to provide recommendations based upon current literature and empirical evidence. Although it would have been better to have conducted the intervention, we believe that this commentary will be widely used by practitioners in soccer performance. Furthermore, as discussed, the opportunity to perform a training intervention in-season with elite soccer players is extremely limited. This somewhat questions the validity of some of the training interventions reported in the literature. Future research may consider investigating individual player case studies returning from injury, not involved in regular match play or lacking fitness (Mujika et al., 2007; Anderson et al., 2019).

CONCLUSIONS

The analysis of an elite youth soccer training program revealed that the importance of match play is a key driver for the physical development of the individual. Our findings suggested that the longer a player went without match involvement, the higher their HR response was in the submaximal YoYoIE2 test indicating a potential lack of exposure to the required stimuli to promote adaptation. It was also evident that a range of other GPS variables to quantify external load had moderate to strong correlations with change in fitness. Regardless of the team a player was in, the increased exposure to training and matches elicited a greater adaptation to exercise. This was all put in practice using the approaches that were identified to be superior within the systematic review of literature, with a total of 40 weeks of data across 3 squads inclusive of 52 players was observed. Differences in match involvement, total distance completed, high speed distance have been highlighted across all age groups, evidencing the requirement for individualised training load considerations to be adhered to. From this it was evident that an understanding of the current literature and methodology to close the gap was required to allow for practitioners to implement practices to ensure whole squad fitness and individual player fitness was improved. Overall, this body of research provided evidence as to coaches′ perspectives on this development, before investigating the effects of a season-long period of training load in soccer, and then finally providing recommendations for players who potentially may not be involved in matches or training enough to develop

To increase a coach's knowledge, understanding and use of research findings, the communication and methods of translation of the findings should be tailored to the individual. Overall, this thesis provides coaches with an understanding of training and match load characteristics to aid in understanding the importance of elite youth soccer players to be involved within matches for the development of fitness. Additionally, it provides research-practitioners with guidance on enhancing the impact of research in applied sport science settings. It is hoped that the data and the research from this project can aid practitioners in the methodology they choose to develop players' fitness in an academy development program. As mentioned in the literature review, a model by Bishop (2008) was developed to call for a change in the way that many sport scientists think about the research process. It is

hoped that the model can guide the direction that research is acquired and used by practitioners and it is hoped that this thesis provides an understanding which can be implemented into a real-world setting (Bishop, 2008).

PROJECT LIMITATIONS

This research project has investigated the relative importance in the importance of physical development in elite youth soccer. Whilst achieving this aim to understand and develop the knowledge in this area, some limitations have been identified from which recommendations for future research are suggested. First of all, the data collection used in chapter 5 is all collected from one club. This club, although the sample was across three teams, the use of only one club poses an issue: generalisability. As only one club was used, the characteristics of match and training are specific to that team, and more specifically the clubs training strategies, tactics and players physical qualities. To improve the strength of this research, a multi club approach in the future may strengthen the applicability of the findings and allow for other teams to be more confident in using such strategies.

The internal training load quantified in chapter 5 seemed to suggest that an increase in time spent training within higher HR zones in turn caused an increase in HR in the YoYoIE2 test. This is in contrast to previous literature, whereby it is evident that an increase in fitness, and therefore a decrease in test MHR would be observed. This may be a resultant of the poor HR traces throughout the season not being accounted for, whereby the research in the appendices which is describing missing data points may be important for future longitudinal tracking studies. (See appendices for commentary on replacing missing data). Such information would allow the practitioners to support the coach by making informed decisions to adjust training programs to allow the external load to reflect the internal load. Additionally, it would be of interest to investigate this point in more of a dose response nature, as then we could provide specific recommendations based upon empirical evidence for training and match strategies.

Another issue which arose from chapter 5 is that when attempting to understand how different periods of time prior to the test was that when 'all' of the training load was considered, rather than just 2, 4 or 6 weeks prior, the correlations got weaker. Possibly any

duration greater than 6 weeks is too much time to account for, it is just too much time to account for, or perhaps it suggests that the training occurring closer to the test has a greater influence on the % Max HR achieved on the YoYo Test. Another rationale for this could be due to the function of the test itself, whereby the % MaxHR is not sensitive enough of a measure to identify relationships that are pushed this far out. It should also be noted that within this study only one physical test was used to analyse the physical fitness changes, and this study was submaximal. Future research should build upon this with maximal testing and also include strength and power-based variables within the analysis.

In relation to chapter 6, due to the worldwide pandemic, a commentary piece was written rather than an intervention, as planned. However, due to the difficulties performing a training intervention in elite soccer, future research should consider investigating individual player case studies of those returning from injury, not involved in regular match play or lacking fitness (Mujika et al., 2007; Anderson et al., 2019). Future research could also consider testing neuromuscular function and strength-based changes in tandem with aerobic fitness, as we were unable to get enough control over the program throughout the season to do this.

RECOMMENDATIONS FOR FUTURE RESEARCH

As highlighted in the limitations of the thesis, single club/team studies often lead to reduced generalisability of research findings. Therefore, future research into the effect of both training and match load data from multiple clubs should be completed. As such, perhaps researchers should invest time to build relationships with other clubs and possibly governing bodies to allow for the potential to share data. Such training advancements would allow for practitioners to fully understand and expose athletes to both the requirements of training to develop a player not only technically but also physically in tandem. Additionally, it was identified in chapter 4 that coaches believe that the involvement in match play was important for the development of a player. It would be interesting to conduct interviews similar in nature with multiple other clubs in an attempt to conclude a consensus on beliefs in this given topic. From the findings of chapter 6 it is evident that further studies need to investigate relationships between additional conditioning sessions and their prescriptions contributing to the increased player availability for match play when required. In addition, limited evidence

exists regarding management of players physiological status during the weekly microcycle maintaining or developing physical qualities to allow for optimal match play performance and should be further researched.

A further understanding in the future of other clubs' ideas around the relative importance would allow comparison of physical development in youth soccer to evolve. In addition, there were only eleven participants involved, a sample which could be increased in the future to provide a more thorough analysis and demonstrate how different coaches at different clubs either differ or agree with the present research. Nevertheless, the coaches interviewed in the study had experience training in top leagues of different countries, so their opinion would be representative of the elite coaches in soccer. Moreover, it should be noted that a key point that arose from this study was that having a clear structure in place within the club, allowing for all staff and players to have a comprehensive understanding of what the main goals of the development process, is key for the overall success.

We believe that more research is still required though which accurately monitors TL in conjunction with sensitive tests to detect performance changes. For instance, when evaluating the application of the outcomes of this investigation, there are many limitations which must be considered before applying the findings into practice. The articles included in this review reported changes in physical assessments across a diverse range of training periods (ranging from 5 days to 2 consecutive seasons). This range of time periods is likely to affect the extent of the aerobic and neuromuscular adaptations that occur within the athletes included in the samples. This makes it potentially difficult to make firm conclusions about the relationships between specific aspects of the training load prescribed in the studies and the change in test performance. The impact of this potential factor on the findings of our manuscript could have been reduced by the application of tighter inclusion criteria, around the adaptation (period) of the papers that were analysed though this would have further reduced an already small volume of manuscripts to evaluate. Other more general factors, such as theoretical and conceptual limitations to accurate training load quantification, the general approach to utilising detailed training load methods, a lack of focus on analysing individual responses compared to group responses and the appropriateness of each individual test may also impact our findings. This perhaps highlights the necessity to improve

current approaches which both quantify TL and measure physical development of professional youth soccer players in research. Within this review there is also a lack of consistency between the measures included, which limits the ability to cross comparison between studies.

PRACTICAL RECOMMENDATIONS FROM THESIS

It is hoped the information in this research project will provide practitioners with a greater understanding of the relative importance of physical development in elite youth soccer, with special reference to the role of match play in this process. The practical recommendations from the present thesis are as follows:

1. We believe that more research is still required though which accurately monitors TL in conjunction with sensitive tests to detect performance changes.

2. Our analysis indicates that a maximal aerobic speed (MAS) test (Gibson et al., 2018), derivatives of the YoYo Intermittent test, (Noon et al., 2015; Perroni et al., 2019), 30-15 IFT (Paul et al., 2018) and laboratory based incremental running tests seem to be sensitive in detecting changes in aerobic capacity across chronic training

3. Coaches, both technical and physical, believed that the importance of physical development within elite youth soccer is very important. Moreover, it should be noted that a key point that arose from this study was that having a clear structure in place within the club, allowing for all staff and players to have a comprehensive understanding of what the main goals of the development process, is key for the overall success.

4. The systematic involvement in match play may be a key driver for the long-term physical development of elite youth soccer players. Periodization of the training should be based on starting status (e.g. starters and non-starters) and match position demands in order to optimize recovery and performance for match-day.

5. The longer in duration an individual goes within involvement in training and matches, there was a decrease in HR of the YoYo IE2, demonstrating the importance of training and matches for physical development.

6. To close the gap between players who receive less training and match exposure the following methods can be implemented:
   - Large SSGs 10v10 would be optimal to allow for a moderate overload in the intensity of match locomotor demands (TD and HS). However, due to lack of players that are available for top up sessions, it may be more useful to use a combination of small SSG (eg, 4v4) and HIT training to elicit the desired responses.
   - Medium and large sized (>165m ^{2} per player) SSG can be used to ensure HSR and SPR exposure demands are met, with smaller sized SSG allowing for mechanical adaptations.
   - Although linear based isolated running drills may be preferable methods for hitting external workload measures, due to efficiency of delivery, game-based drills allow for replication of sport specific movement patterns to be met.

7. Individualization of the top up session is key. This should be based upon what the player has achieved in relation to exposure to each training variable throughout the previous week. Where a player has not received adequate stimuli, this should be the main focus of the session.

CHAPTER EIGHT

APPENDICES

Figure 8.1 Interview Schedule to understand Coaches' perspectives on the relative importance of physical development to the success of elite youth soccer players

Background

1. *At present, there is little research into the coaches' philosophies on the relative importance of specific components of the training process (i.e. the physical development) of youth soccer players compared to other aspects of development (i.e. tactical and technical abilities, Suzuki et al., 2006). An understanding of the views of these key stakeholders in the development of young players would enable insights into the relative importance of the development of physical traits to overall performance. Such information would provide a platform for the planning and implementation of more appropriate holistic player development programmes. Therefore an aim of this research programme is to understand the coaches perspective on the importance of physical development to the successful performance of elite youth soccer players.*
2. *This protocol has been designed by the research team involved with the PhD Thesis titled 'Physical Development strategies in Elite Youth Soccer'.*
3. *As lead researcher and based within the football club that the research is taking place within, the coaches have been recruited using the following criterion:*
    a. *Must be coaching teams 15s-23s at this club*

The Interview will follow this structure in terms of there will be three major parts: The opening, The Body & The Closing.

Opening

1. *(Establish Rapport within the interview)- General introductions and initial conversation including the reasoning for the interview today.*
2. *(Purpose)- I would like to ask some questions today about your philosophies in terms of developing elite youth footballers. They will start broad in terms of looking at the four corner approach and then I will ask some more specific questions around opinions on the relative importance of physical development.*
3. *(Motivation)- I hope to use this information in combination with my second research question to allow for observations and analysis in relation to the way that training is implemented within the elite youth developing footballer.*
4. *(Time Line)- The interview should take roughly 25-30 minutes, this includes time given for the structured questions I have outlined below and time for use to explore certain topics in more detail as appropriate.*

Body (knowledge elicitation using questions related to the purpose of the study).

Stage 1- Introduction & Coaching background

Main Questions	Probing Questions
How did you become a coach?	
Why did you become a coach?	
How many years have you spent coaching?	What format of the game (senior/academy) have you coached and to what level?
Can you give some details of the qualifications you have to get into this role	

Stage 2- Critical success factors and development processes of elite youth soccer

Main Questions	Probing Questions
What are your thoughts on what is regarded as a 'success' within academy soccer	
How important is the match outcome in elite youth soccer	How or do you view this as an indicator for athlete development
In your role, are you developing players and/or people?	What are the main attributes of these players/people?
What are your thoughts on development in youth players (you mentioned earlier about specific attributes that you are looking for in a player so how do you see this link in?)	Do you categorise development into the four corner model, where do the players attributes fit into this model?)
How do you currently measure/quantify development in your players	
If you do categorise development into the four corner model is one corner more important than the other	Are they different for specific individual needs?
In relation to the four corner model, when structuring a training session/block what is the main area of focus	How do you account for the individual needs of different athletes?

(Interim)
So now we understand your perceptions of player development as a whole, I would like to delve a little deeper into your thoughts regarding player development from a physical perspective. This will be to understand more around how you plan short term micro-cycles so both daily and weekly sessions and how this fits into your long term planning. I am going to try and understand everything from drills and activities within sessions to how you see the importance of physical development fitting into each individual players program.

Stage 3- Specific Thoughts on the physical development of youth soccer players

Main Questions	Probing Questions
How important do you see the physical development in relation to other aspects of player development	
How much are the sessions designed in unison between coach and fitness staff so both technical work and physical work is developed upon?	Do you use the four-corner model designed by the FA as a basis for this? Is this in completed in isolation or as a whole between Physios/fitness staff/Football coaches?
Is there a drive from all parties (coaches & fitness coaches) to get appropriate physical adaptation for the players?	Is this integrated within the session or is It a separate component delivered by the fitness staff
Do you plan training to ensure freshness when it comes to the game on Saturday?	Do you mind if a player is slightly fatigued however throughout the training week you know they have hit their individual development requirements?
How do you measure physical development and what strategies are in place to enhance potentially weak areas for individuals?	
How important do you believe the extra physical work is for players in terms of development	Do you deem the gym and pre training work as important for player development
If physical development is deemed as a marker of improvement a player needs to work on, would you ever consider manipulating training if it was identified as more important to do an extra training session with the fitness coach or an extra gym session.	
How do you consider different growth/maturation rates?	Are coaching practices changed as a result. Do you look at the data that is produced by the fitness staff to manipulate this.

Closing

1. *(Summary)- You are involved the daily training and development of the elite youth footballers at this club and the thoughts and responses to the questions outlined above give an indication as to how you the players are developing.*
2. *(Maintain Rapport)- I appreciate the time that you took for this interview. Would there be anything else you think would be helpful for me to know regarding these topics so when I conduct the analysis on the training load as mentioned above to see if the most effective development plan is being administered.*
3. *(Action to be taken)- I should have all the information that I need to conduct further analysis on the training load now. I will give you feedback on the questions including the responses to training/match feedback in due to course. I can make the transcript available if you wish to see a copy.*

Additional Tables with Raw quotations relating to each relevant section of the study.

Table 8.2 Raw Quotations from the General dimension described as Academy Success

Coach	Raw Quotation	Theme the quote relates to
Ewan	My version of success in academies is to produce players. So players these players that First can play at, the first team of which ever academy it is that might be Secondly, to play and have a career in the game, whether it's at that club or somewhere else.	
Henry	Success for me is being able to educate somebody to then be able to potentially play a professional level.	
Jordan	Success for me in Academy soccer is making sure you maximise the potential of an individual. And now in doing that obviously along the way, players won't reach the required reimage so they will naturally drop off. In the organisation we work in if you're working with a player towards the end of that process or that pathway. Success should be judged on making them a professional player where, whether it be with Liverpool or elsewhere.	
Frank	So my personal feeling is success is giving somebody a career any level. Playing career at any level so playing in League two League one Equally, you could argue that a success is also as much as we have individual player development. I still feel it's massively important again, that you are able to work as a team and that you have the drive to win. And that drive should hopefully come out and so your leadership skills and you lead by example and drives the team with you. And I think that yeah so wouldn't good like a player being an individual superstar but if you can't play for the team then I still don't think he's going to fulfil his potential as much as you should do as you move on so he goes into the first thing.	
Callum		

	I think the bigger picture is sounds a bit corny and all that but I think we just got to from our point of view we talk about the selection of players into our first team but I'm not convinced that's probably the best barometer of your Academy because the situation of the first team has such a massive effect on whether you get players through or not and
Dave	what can look like a really positive sort of crop of players. Yeah, they may, you know, may actually only be getting an opportunity because, you know, the first team becomes you know top six rather than top four
George	Success would be equipping a youth or a junior Practitioner with the requisite skill set to physiological capabilities and tactical insights to perform at a first team level.
Ben	So kind of measuring success at Academy levels can be quite difficult because it's very circumstantial
Issac	We'll get one or two through but then also trying to make sure you've generated the experience those lads then going to have a professional career.
Henry	still think success should be seen as somebody exiting the academy and still having a career, or having the tools to have a career if that's what they wanted to do.
Callum	It is a cliche but good people coming out here Academy, offering is really important. And what I mean by that is well rounded people
Alan	Selling someone to someone that maybe goes out, doesn't quite get to where we think they can in terms of the first team but we create a sizeable income from them, then that will be the existing success. That will help us to recoup whatever it is that we spent, I think we just probably centre our training around players that we think are going to and have the ability to progress.
Alan	Primarily it is getting someone into the first team. But not just the first team, someone that is capable of helping that team who can go in and win trophies!! That's the first thing. That's second criteria is that we are not to be seen as a charity. Whatever we spend we have to get back so success is also generating enough income that the club see

	value in the academy system you can do that over a variety of ways. So you can do that, obviously getting someone's the first team is the most linear way of doing that so sitting on the bench value to that because you don't have to pay a senior player to do it.	Academy Success
Henry	Be that at the academy that you're working on, which is probably gold standard if been at Liverpool if we can create a player that's going to play firstly for Liverpool fantastic.	
Dave	I guess players progressing into senior football would be a broad sort of measure I know that there's a need for that because bear up the clubs obviously are investing a lot of money into academies, they want to see a bit of a return on a return but I guess you could look in terms of the finance that it brings in in terms of sales and stuff where then you know what's somebody like a trend that goes	
Henry	Be that at the academy that you're working on, which is probably gold standard if been at Liverpool if we can create a player that's going to play firstly for Liverpool fantastic.	
Dave	I guess players progressing into senior football would be a broad sort of measure I know that there's a need for that because bear up the clubs obviously are investing a lot of money into academies, they want to see a bit of a return on a return but I guess you could look in terms of the finance that it brings in in terms of sales and stuff where then you know what's somebody like a trend that goes	
Issac	What are our aims? What do we want to expose these lads to what are the demands at first in football? Because ultimately, that's what we're preparing for.	Clear Academy Pathway of Development
Alan	I′ve always considered football more as an art rather than a science Its not an Objective Science.	
Frank	They also have a massive appreciation of the physical, that's just come from like having a philosophy within a club and we've been.	
Callum	That's the reason why we played so many games this season because you're trying to prepare them for the next step you got so lead to Ligue one championship if we go alone in Division. 444 games 46 games, close last season.	

Issac	Then I think just being able to develop those people to have good conversations with them be thankful for the work that you put into them.	
Alan	We want to make good human beings, people can go out and represent themselves and family and somebody While they will be the club as well.	Life outside of football and the player as a person
Ewan	players that maybe don't go on another full-time career, but we'll have from the world of science, analysis, making sure that we've got boys that come through the programmes all the way through to have some sort of success in their lives. And they, they can be successful in whatever they turn on to success. I think the first step is to come up for people to help people become really, really nice people to grow up to become your women or men or whatever it's going to be.	
Jordan	I think you're developing people first and foremost, now that's obviously not why I get paid. But to shape your mindset, and to shape behaviours of individuals, eventually, if you do it right, aids development, and often speeds it up.	
Callum	We've got the divided, something that's bigger than football that makes sense, the more like, you know, play seems safe. They come in have an enjoyable time.	
Jordan	You're looking for a hunger. Yeah. Now what I mean by that is, is a natural desire to improve, get more get better.	
Callum	Not too much too soon. Don't put them not being too professional too soon	
George		

	I think you've got to develop both in team sport, and I think somebody who isn't a well rounded individual who isn't conscientious or. I say forthcoming coming, probably going to be a detriment to the team environment. They're going to struggle to work cohesively within a team. And that place is struggling on staff and resources, I mean we've all worked with difficult players.	
Issac	Can you get that foundation of strength into the boys and to prepare them because you're probably not going to do that as much at first in football?	
Alan	Well in the academy it's different at different phases so when you're younger everything looks a bit different so you probably prioritise technique Of course you can apply it to your senior skill but as you get older I think acquisition plays a little bit less of a part. So if you're mo Salah now. How much time do you affect honing a technique, he probably polishing a technique that the minute you're breaking a new technique or starting from scratch.	
Callum	We don't want any 11 to 12 on nutrition and following these programmes and Doing this and do not just let them be kids let them. Don't wrap their whole identity, around the	

	football club, the percentages will show you that. Very, very few are going to make it as footballers.	Considerations depending on age and stage of development
Alan	Now it's a physical programme to develop the first teams it hasn't been developed with kids So that was mixed with education and things like that. There is danger of not doing very much at all.	
Ewan	after a period of time those numbers will present readings that we can look at so actually is a little bit of a theme on this that he loses 60% So it maybe start with another technique, etc. are starting to facilitate a development in whichever area it was that we found. So, we use data, and it helps shape our views that we see on the side of the pitch when we watch games. I think we've got the EPPP which has come in has created a whole host of new rules, some of them are really good. Yeah, it's like, you've got to provide so many hours of training every week for a 12 and 14 year old I think it's really dangerous. Yeah, I think, I think, more often what happens is, yeah they become too professional to see, and it's like overkill specialisation,	
Callum	So, I would certainly say at a younger age, I certainly think you've got a real opportunity to, you know, at the real development age of, you know, 910 11, you got a real opportunity to develop some technique. Yeah. Which I think can be extremely, you know, which is extremely important. Whilst also probably, you know, developing resilience at a at a really young age, you know, that's not to say you don't make that sort of, yeah, like, you know, a boot camp or, you know, you know, what I'm trying to say is probably, you know, you know them outcomes in terms of can,	
Issac	then typically what works well is they come over to me for even if it was eight minutes if they're technically quite efficient, what they're lacking in the speed. And that's something that I get some individual time for	
Callum	just let the kids be okay	

Callum	You've got a generic program which players work within, and then you will have players who will fall away from that due to the lack of mental desire.
Henry	I think it depends on the individual, if you have a lot that's sort of a fantastic technical play, and all of a sudden the physical side of it becomes a focus for their development.
Alan	That's completely different to how you do it to 19/20 year old – it's the same principle but it's understanding its different in terms of the importance of methodology.
Ewan	When we're working with players on development areas to continue to develop, it doesn't just cover one area a lot of it would come across all four areas, at least two or three areas
Issac	What's going to be their super strength, it's going to make a premier league football, and then we'd get a hell of that. And then what's his weaknesses? And then we can try and chip away and just try and divvy up between the staff as best as best we can, really.
Alan	Its an impossible question to answer because if you're talking about someone that is genetically blessed and is already an amazing athlete. Yeah, then it's probably a bigger priority. If there is a strong. If they're being able to sort of decide that the best human genetics points, physically theyre already a gifted athlete then of course they can improve that might not be as important as if they can't track the ball or pass the ball or finish or whatever position. They have, they're actually not as important as the others, all I think that its c completely up how important the physical part is depending on the person that you're working with.
Ewan	From an individual point of view is constantly looking at what the outstanding corner is and trying to enhance it, and then in the same breath is what's the weakest corner and making sure that's our way before sure that we're less than down,
Henry	He's complained of growth related injuries. And we monitor we show up adapt and manage lots of shoe, no work this summer work better with day on day off, and we get it upstairs from the report, no issues on the screen and the weekly screen in there within

	the limits. And for us, we do not as acceptable for them, then to continue with the trend and not weak. I would argue that we don't have much of a team based programme. Okay, I would argue that it runs in tandem to several individual needs.	Individual Needs within a team setting
Jordan	The team is just the team is just there to serve the individuals. That's it.	
Callum	There'll be part of a session, I think the session we saw within the session is both so this team needs a 23 level, there's also still individual work going on and unit work, which certain players, that we may deem as like having the potential to step up and play for our first team, the focus will be around them.	
Frank	So you want to go through top strength training or you're just happy with, just like yeah, just strength training, and strength training. What also replicates or surface and pressing actions and we'll do that on a pitch as well. Execute action and work in a high intensity, or if it's more like a, being able to recover.	
Dave	Yeah, you want to definitely want to win. Yeah, you know, but not at the detriment for the best interested individuals but I think people get a bit side tracked without it but if you can talk a bit wishy washy about winning.	
Dave	I guess, if you've got the full sort of squad together, then you're looking at what sort of the betterr players in that squad would need, along with sort of some sort of eye on what you've uncovered in terms of the games.	
Dave	So it's not ideal to miss training but if if you know that that's that's really important to him and you all agree some more than a point of view that's focused and if that means that that change and then puts him at a slight disadvantage when you go into playing the game and I don't really see that as being an issue, I think it as long as it fits in with what you're doing with them if you're just doing it, you're just doing it, we're going to give them a lot	
Dave		

	I think that's where you look at their physicality, their individual physical capabilities or capacities. From that workout their shortcomings, improve their strength limit their weaknesses. Yeah, they're all different. From this, and that's probably where visualisation comes in that you notice it do a role, you will need to be able to do X, Y and Zed and their, their current level their current capabilities are somewhere with the	
George	somewhere within range of that if they're in a, you know, an elite Academy setting so it's your job to then see who needs to work on what is a strength development is it a technical issue is is this something that he's really missing, that you think you can have a real development or a real sort of real in a real car there, you know, fluffy, where you can really make a difference.	

Table 8.3 Raw Quotations from the General dimension described as the importance of winning matches within academy soccer

Callum	We don't mind if they are fatigued going into games. Because ultimately you need to get those adaptations ready for when they do come play two games a week
Ewan	

	I think at the age group I am working at now I have no concern with the boys going into the game fatigued or tired as long as they're not going in with, with a big risk of injury. I think that they, they have to. They have to understand how to play tired, if we're if we're doing our job properly and we're trying to develop them in all of the areas of their game, including the physical one	Playing in a fatigued state while minimising injury risk
Ben	You know I've got no I've got no problem with that at all I've the only the only concern I would have is if we were had that tinkering on the edge of the boy getting an injury	
Callum	No, no, no, no, no, you don't mind them playing fatigued unless you're coming up from injury or you wouldn't have to do that.	
Issac	It's the skill of the practitioner to make sure that's dosed in the right way to limit the amount of risk of injury but then also to drive performance. We can't always be trying to reduce injury we've also got a strive to increase performance capabilities that these athletes	
Alan	I have no problem seeing the game as another phase of training. I believe of course there has got to be adaptation. I don't mind going to the game, slightly more fatigued than I normally would do for a first,	
Jordan	Yes, to a certain extent, but could they be fresher yes well that will be a detriment to their development.	
Frank	He wouldn't say that the outcome of the game is important. It is really about like how did the team play. How did the individual players do? The results will come secondary. I do think though when you play certain opposition, City, you want to see how you compete against the best players.	
Callum	That's why we enter in all those competitions and season because they have to get used to playing under fatigue	
Issac		

	The older that they get, obviously it gets more competitive. The FA youth cup, there's a lot of competition placed in there.	Importance of winning matches in academy soccer
Alan	It always matters, it matters to the kids, it matters to the coach I have a sliding scale where that to come to the school. If you've ever watched an under 8 game have you ever counted the score- you lose count, so winning and losing is less important. But as you get older. The importance becomes more significant	
Henry	The older you get, the more important it gets. I don't think there's any point in producing players who have not had to manage a game or play to win.	
George	Think you varies at different levels, and don't really want to sit on the fence because I know that that's not very helpful, but as you progress through the more senior ranks of youth football so when you become full time. That needs to be the needs to be a time where you need to learn how to win. The result might be important because it's then reflective of your ability to do your job as part of a collective team. So I think there's a greater importance as you approach those more senior ranks.	
Ben	As the boys get older, I certainly think the outcome has responsibility that come with it a resource of responsibility.	
Henry	I think a lot easier to deliver messages when results are good, whether you're working with adults just natural buying whether football or any other organisation if it's successful people do want a piece of it and they do want to listen to you want to do want to understand how the cogs work wherever you can have just as go to work and machine shaping up produces good results at the moment in time, it doesn't get as much attention so that's always been my viewpoint on results is I don't think it's the be all end all and it certainly doesn't make players, and I'm really clear on that. But I do you think it does, it does help the process because obviously a positive environment is one that's, that's better	

	for learning and better for improvement and winning definitely upgrade positive environment,	
Jordan	It is important that you have the drive to win. And that drive should hopefully come out and so your leadership skills and you lead by example and drives the team with you	
Frank	I think winning is like habits so they obviously about with the England, youth set up at the moment, they've just won yeah but a few tournaments and hopefully, that becomes a norm so as they become professionals, and older, they actually carry on with that so I think there is a place for that, where they do need to have some success, but I don't see that as individuals, see as part of the programme.	
Frank	The match is just an extensive training. It gets a little bit more important. The higher you go, obviously, yeah. The emphasis should be on the performance, the process.	
Callum	Probably how you get there is.	
Dave	The easy thing would have been right experienced player right back but no, he actually said I want to see how you're going to cope.	
Alan	Primarily it is getting someone into the first team. But not just the first team, someone that is capable of helping that team who can go in and win trophies!! That′s the first thing. That's second criteria is that we are not to be seen as a charity. Whatever we spend we have to get back so success is also generating enough income that the club see value in the academy system you can do that over a variety of ways. So you can do that, obviously getting someone's the first team is the most linear way of doing that so sitting on the bench value to that because you don't have to pay a senior player to do it.	
Ewan	My version of success in academies is to produce players. Players these players that first can play at, the first team of which ever academy it is that might be	

	Secondly, to play and have a career in the game, whether it's at that club or somewhere else. Yeah. And then, in terms of the actual football side of it.	Manipulating challenge points for the greater good
Henry	Be that at the academy that you're working on, which is probably gold standard if been at Liverpool if we can create a player that's going to play firstly for Liverpool fantastic.	
Dave	I guess players progressing into senior football would be a broad sort of measure I know that there's a need for that because bear up the clubs obviously are investing a lot of money into academies, they want to see a bit of a return on a return but I guess you could look in terms of the finance that it brings in in terms of sales and stuff where then you know what's somebody like a trend that goes	
Frank	He really wouldn't say that the outcome of the game is important. Yeah, you know, so it is really about like how did the team play How do they. How do the individual players do. Yeah. The results will come secondary. I do think though when you play certain opposition so wherever it's like I say, I manage the city or you want to see how your base compete against the better players. Yeah, but then again that's not the result. So, if we out payment city and lose three one.	
Callum	I don't mind if they are fatigued going into games. For me, that's really important as fitness coaches, because you know that you can push them a bit harder in training.	General freshness for match play
Jordan	I think a lot of the habits and parts of the culture that we've got right we've certainly not cracked it but I think we're a lot closer than what we were certainly when I joined.	Desire, Motivation and resilience
Frank	If you′re trying to develop physical, you′re also developing mental, for me it all links. In reality it′s hugely important like the mentality and the desire will ultimately be overriding if you have got that then you won′t become a professional player.	
Callum		

	You've got a generic program which players work within, and then you will have players who will fall away from that due to the lack of mental desire.	

Table 8.4 Raw Quotations from the General dimension described as the coaching process

Coach	Raw Quotation	Theme the quote relates to
Issac	In terms of the art of the coaching, it is trying to pick up all the different skills from the sports scientist or psychologists, try to blend that into a session	Blending Knowledge and multidisciplinary expertise into Practice
Ben	Due to the demands that are placed on me as a coach, what is expected at the end of the programme you have to blend it all to one	
Alan	You've got to be able to produce the demands of the game but how you get them there is the art of it.	
Henry	He's got a very good understanding of Sport Science and he appreciates where we're coming from. (Talking about the technical coach he works with)	
Ewan	My role is to is to take the information that's given and put that into the, into the picture that I have in terms of the development and to work out If it's viable if it's the right thing.	
Issac	There are loads of different individuals within that who have got different needs. For example, he would always say to me, there is a physical side of it, how can we get that in the game first?	The importance of Individuals when considering designing whole team practices
Ben	I kind of look at the fitness side and physical development if that is if that's maybe the right, maybe it's not.	
Callum	I think the skill is knowing when to use it at the right time for your benefit.	
Ewan	That's all got to be related to the game that they play. So you can't just look at the data and say he has covered less ground in the game which he's winning 6-0 as he doesn't have to run	
Alan		

	I′ve always considered football more as an art rather than a science. It′s not an Objective Science.	Is objective data important or can a coach use previous experiences to design practice?
Frank	Coming away from like sort of any objective data, it's very much like when they go up to the first team, what is the feedback from football coaches and fitness coaches, how do they look in the gym, when they're doing their pre training, in the Rondo's. How they look in the games are they looking fit a little bit sharp, have they got control over their body. And so I think that's probably the biggest thing I see.	
George	I think a lot of mine goes off previous injury history and feel.	
Ben	I don't think we ever take the place of, of the parents. And obviously, I've been very fortunate, you know, through careers in terms of teaching and the Academy, work with some really good kids.	Additional Coach Responsibilities
George	But I do think we as practitioners have a responsibility to develop a well-rounded individual within that approach.	
Callum	you are doing really is providing the players with an opportunity, a platform to come in and develop a playing football, like football play football.	
Issac	the coach will always have the final say And in terms of the art of the coach, is trying to pick up all these different skills from the sports scientist or the physical side or psychologists	The coach comes first
Alan	It′s coach led but the sports the fitness coach was, of course, part of the consultation maybe or could give advice.	
Ewan	Yeah, I'd like to think that as a member of our group of staff that they could approach me and say, can we incorporate this into today's session. It's really important that you can come to me and give me a thought about the session.	
Henry	At this club, but something in the past as well, if we go back to the other areas, I think it's important that strength and fitness in s&c coach performance coaches whatever you want to call is that we	

	understand what our role is. We are support staff ultimately.	Holistic Staff approach
Jordan	We will converse prior to every session	
Frank	Holistic approach, it's not like we work in isolation to the coaches. They also have a massive appreciation of the physical so yeah, that's just come from like having a philosophy within a club and we've been.	
Dave	So we come up with what the initial kind of a session would be, he would he was quite good in terms of understanding that that those days and what each one should sort of incorporate so he would usually come up with something. And then, Jack would obviously help, sometimes around you know volume and how many sets we're going to do	
George	If you ask everybody in a group setting, everybody would have an agreement that there is appreciation for the physicality of the game. But I don't think that's always reflected in the way that people construct sessions or what they prioritise. Sometimes that could be due to a lack of education around it. Other times I think it's due to just a change in in priorities, or, essentially what excites people.	Is what people think they are doing, reflected in practice?

Table 8.5 Raw Quotations from the General dimension described as training periodisation for player development

Coach	Raw Quotation	Theme the quote relates to
Issac	mainly from the game, I think, yeah, I think that tells you a lot. And what are they struggling with one v one footwork and then try to link that into the technical and tactical side.	Individual work relating to game demands
Ewan	So it works backwards and names individual development, style and the performance of the team to allow the individual to develop or individuals. And then of course winning comes later.	
Henry	So, obviously football is what we want to try and get our adaptation from. So I think that's the most important thing but then if we can start to share that and change practice, day to day week to week based around the physical objectives, then that's when we get the best results.	
Frank	yeah well work back from the game or from training with that player that's still my barometer.	Top ups post game
Frank	So the players who play regularly are playing, and then they're involved in like a recovery matchday minus two minus one and they're back into a game. So it's not really like many minus threes many fours we get that sort of peek into them. The ones who tend to do the running of the ones who don't get much of the game time so if I say travelling four or five on a day after the game with the subs in the sport.	
Issac	Suppose it depends on the day. So if it's their bigger day or extensive day, then you try and overload the high speed running and sprint	

	distance. But how you do that is quite tricky because you might have different players, there might be a few injuries. So I think it's footballs really hard to say, yeah, we've overloaded this in a session design.	Session and Practice Design. How does session design and training periodisation affect the development process?
Callum	Yeah, it was just the emphasis changes depending on where you are in the week, and where you are in terms of your games programme.	
Callum	This is gonna be, you know, so the physical output would become probably more would be slightly more emphasis on that than it would be on the technical tactical. I suppose you would there be a sort of there, we used to work off of tall a rough plan in terms of how we would structure the days Yeah. You know off the sort of the resistance today and the speed a strength, not yet, so we do have that, you know, not regimen, it may be, you know you'd know that, you know, beginning of the week one of those two days is going to be a fairly decent hit resistance wise it maybe there's some counter attacking drills and things like that.	
Dave	I think each day has probably got a different physical component that you need to. It doesn't necessarily have to be a tactical periodization model, I think there's got to be a variety of stimuluses across training block when they come in one week, two weeks, three weeks before. I think I would prioritise. The physical outputs by suggesting areas or types of training, whether that be technical or tactical or physiological outcomes. So if we're looking for extensive work or a cardiac response can we keep training continuous, so even if it's a technical drill can we maintain a continuous flow through it.	
George	Well, if we wanted to and adopt a first team strategy then you could argue Monday through Friday plus two. Yeah. And then you say, okay,	

	Wednesday, Thursday, Tuesday, Wednesday, they're gonna get a hit. It's a Thursday they're college and won't do anything then Friday they're preparing for a game then they'd only have two training sessions.	
Alan	Yeah, not going to be enough to help develop.	

	Yeah, but you got to be very careful that you want to adopt a periodized model which is now sort of like been accepted, I'm not sure it's a developmental model.	Is training periodisation a hindrance?
Henry	we have been on more of a sort of like a player recovery model, rather than trying to achieve adaptation through training but not because that's the philosophy of the staff if that makes sense it's the constraints that have been put on us.	

Table 8.6 Themes extracted from section 3 of the interview schedule.

Coach	Raw Quotation	Theme the quote relates to
Alan		

	I think Your objective data that you can get on a player, the markers that you might want physically or technically your numbers anything else that only paints part of the picture, yet but really I don't think it's ever going to substitute for what your eyes see someone feels.
Ewan	So probably physically probably one of the easiest ones, because when we use GPS monitors and HR monitors and every session is catalogues and when we have the data back from all the time it's quite, quite easy for us to see the trends in high speed distance, distance covered or whatever that might be. That's all got to be related to the game that they play. So you can't just look at the data and say what is covered less ground in the game which hes winning 6-0 as he doesnt have to run
Jordan	We do our benchmarking, we do have numbers, we do have KPIs and we do know what people for years ago were producing at those ages in those positions and we do know what first team players produce as objective as it can get me from that side of things,
Jordan	So with that you do formulate a view, and obviously then it comes on conversation and planning around the individual development and making sure we get out now I think a more involved in the, the application process development and the sort of find in the, the areas of strength or weakness or identifying what work needs to be but I think then when it changes over to
Frank	So just coming away from like sort of any objective data, it's very much like when they go up to the first team, what is the feedback from football coaches and fitness coaches, how do they look in the gym when they're doing their pre training, as they look in the Rondo's how they look in the games are they looking fit a little bit sharp, have they got control over their body.
Dave	I think its perhaps a misconception of development, I think that you can search for numbers. Where is it actually useful though? You can never

	factor in the quality of opposition, and you know I think sometimes the numbers almost become a conformation bias. Sometimes we try and hit physical numbers to the detriment of the development.	Objective Data
Dave	For example, I know he's been working on a specific run, and then he makes it in a game and you are happy because you almost are justifying the work that you have been working on in training.	
George	We use physical tests, as well as a multidisciplinary approach with the other coaches. For example when we see potential performance detrimets or gaps in the game we have objective data to back up our subjective views.	
Ewan	I don't think there's a perfect way however I always think of the people that don't have to train that will be really good physically.	Importance of Gym work
Jordan	You want players that can cope with the demands of the modern game, and the modern games but the physical.	
Dave	I think it's massive, I was it was a real blind spot for me my until four years ago really. He showed me these stills of like their movements and think you know that stuff that you take. I could not believe some of the stuff I see is like the difference in like their flexibility and there. If you like there was one where it's like, on a bench or like I said reach tests often got the differences unbelievable.	
Dave	To actually get them out to training in the right mentality and right intensity, pre training is key for this. The additional work Is required in order to develop their physical capacities and capabilities to progress. That is why gym work is really important.	
Alan	One strategy around it which might be kinder for the boys realise they can't quite get over there and actually better to be riddled with injuries, but at least they know.	
Ewan	Yeah, I don't think they should. I think they should do as many sessions as they can, within reason, obviously. I don't think that we should ever put them at risk or harm but rather than avoiding. For instance, I would	

	always encourage.
Henry	He's complained of growth-related injuries. And we monitor we show up adapt and manage lots of shoe, no work this summer work better with day on day off, and we get it upstairs from the report, no issues on the screen and the weekly screen in there within the limits. And for us, we do not as acceptable for them, then to continue with the trend and not weak.
Henry	It depends on how effective the plan is, if we have a lot who is displaying like mild growth alerts internship, it might be knee pain, like just generic soreness fatigue. If we manage him to the stage where that player can then not lose training days. Yeah, maybe training minutes through modified sessions and adult thing we have as big an effect, because every kid's going to go through growth. And it's going to affect them differently through others so we have to be prepared for the father at these age groups
Jordan	We're the ones making those decisions, and every decision we make is for the best on that particular individual it's not for the team certainly not for the staff to get results as we discussed earlier it's all around what's best for that individual, and maximising their potential within the organisation
Frank	Yep. You know, for them to miss out the occasional training session to try and minimise the risk of an overuse growth injury, which can then put them play off for three, three months. I think is a far more sort of sensible and reasonable thing, and would improve their chances of becoming a player i think you know once you start getting these bigger injuries, I think it's very hard to get out of that cycle, and actually psychologically somebody's been injured for three months at a time and potentially having to go through that again, that, you know, you could argue can make them stronger also could also be potentially damaging they fall out of love with again and again to maybe their body

	composition gets poor etc I don't know but yeah I think players should be modified to the growth and then, yeah, yeah I just think that if you look at risk versus reward. I know that we talked about working back from the game as well as make sure they get gained exposure. I agree with that as well. Yeah, I think, at times. Yeah, the player the coach everyone needs to understand that what we're doing it for in the players best interest.	Modified schedules on an individual basis
George	I think it'd be highlighted as growth and maturation, like let's say Adam used to do PHV stuff which can also be more of a consideration than purely skeletal maturity. It probably comes down to feel once again and although there is some objectivity in you know bodyweight, muscle density and things like that a lot of mine I think goes off previous experiences and feel.	
Ewan	I think that there are certain days that players are going to run, or they are just going to focus on the footwork, on the way the dead body moves. So I get the techniques and mechanics all the time of their time, when they turn to certain areas that I can relate to as well and that's it it's a very. It's not a straight-line sport, you have to twist you have a multi directional sport, sometimes to really hone down on those things wants to get better every single time it gets to the physical elements	Integrated staff approach to development
Henry	Occasionally, there will be times where you might have five or six players for whatever reason and it's, you won't be able to hit that specific component that you want, so occasionally we might come out and do some physical work. But yeah, in terms of the football side of it is, it's an integrated approach where we use games on certain days we use certain drills on certain days at certain times on certain days to to try the the metrics that we're looking for.	
Callum	We always, always try to do within the football. Yeah, always. Having said that, I still thought there was a place of time and a place for separating the physical from the football sometimes.	

Dave	I'd say. Up until now, probably has been more integrated. Yeah, but I think because of that stuff being said there about the smaller groups with the area size and so again the physical numbers without the football	
George	From a physical standpoint it's the usual ones just speed, strength, stamina agility, all the things that we deem to be sports specific skills that that can then help them perform better on the pitch.	Development through match play and games
Jordan	we will begin to use that to at least signpost us towards some of the areas of development and then that then gives you something to track over time.	

How to replace missing data points in longitudinal tracking studies

A subject of interest, and potentially a limitation for tracking training load in elite soccer in general is that data points become missing and average data is input to create a 'best practice' average score. When collecting my PhD thesis pilot data, the season before the final data collection, there were a vast number of missing data points, whether that be due to signal dropping out, players forgetting to wear them or the unit running out of battery. As such I wrote the following piece prior to the data collection itself to consider perhaps why these things happen, how I can limit the amount of missing data points for my final thesis and hopefully put in place a plan of action to make my data collection as 'robust' as possible. I have included it in the appendices rather than the main body of text as it is merely a brief commentary and not a detailed research paper, but I think it was something of importance to include regardless to demonstrate I have considered this particular potential issue.

Title: How to handle missing GPS data? How can practitioners limit the 'damage'?

Introduction/Background

The advancements in technology within elite sport has been two-fold in the last ten years, with technological advancements in player tracking systems leading the way regarding analysing physical performance and prescribing sessions. However, as always this comes with the requirement to ensure that the data that is being collated in both valid and reliable in its measurements. Once there is an understanding surrounding what measurements are being collected the next issue seems to be how accurately is the data being collected and how many missing data points and errors are there. The aim of any practitioner is to limit the number of inaccurate data points in order to maximise training load data collection and the prescription that follows. This commentary will aim to provide recommendations and practical examples regarding the notion of handling missing data.

How does data become missing?

So how does GPS data become missing?

It is widely recognised that one of the main problems of collecting longitudinal studies is attrition. This is another term used for the situation that not all subjects all data in a study design and is usually seen at the end of a clinical longitudinal study however in relation to collecting daily GPS data this could be at any time point.
There is a clear distinction made between the different types of attrition which can be seen below:

1. Missing completely at random (MCAR, attrition is independent of both unobserved and observed data)
2. Missing at random (MAR, attrition depends on observed data, but not on unobserved data),
3. Missing not at random (MNAR, attrition depends on unobserved data.) (Koraree, 2008)

Information regarding the type of attrition and the possible determinants of attrition is important for a proper interpretation of the results of longitudinal data analysis. This can allow for the data to be best replaced accordingly.

How can it be replaced?

What should happen with missing data?

There are a couple of ways to best interpret and replace missing data files, many which have been seen within the realms of space and navigation-based data. However, when it comes to the world of sport and more specifically soccer it would be great to have a generalised approach for practitioners to use to replace their missing data.
Firstly, it should be noted that this process is high complex; with inferences and estimates without having any real data to observe is hard to manage. The method that seems best suited for soccer and specifically replacing missed GPS data is via 'likelihood-based methods' which require the specification of the joint distribution to be known and how much of the data is missing. This can then be analysed further and specification can be classified into two

types of models: selection and pattern-mixture, (Little 1995).

- The selection approach models the hypothetical complete data together with the missing data process conditional on the hypothetical complete data.
- The pattern-mixture approach models the distribution of the data conditional on the missing data pattern.

Most of the literature in terms of replacing this therefore focuses on maximum likelihood methods of estimation. Some of the data is nonignorable missing longitudinal data, which requires to be replaced somehow – so sometimes a 'best estimate' seems the superior method.

Maximum likelihood (ML) estimation has been extensively considered for the normal random effects model (Laird and Ware 1982; Jennrich and Schluchter 1986). The standard approach is to take the first and second derivatives of the likelihood based on the marginal distribution and use Newton–Raphson (based on the observed information) or Fisher scoring (based on the expected information) methods as the basis for iteratively obtaining the maximum likelihood estimates.

In lehmans terms this would mean; *'understanding the information that we have got, look at what the data is expected to be, compare with means and averages of peers and create a ML estimation'*

Another approach is Predictive mean matching: similar to above the process follows: matching at the item level (PMMitem) and at the scale level (PMMscale) using the REGPMM option from the MI procedure with the default number of the closest observation being implemented (Little 1995). The imputed score can therefore be replaced by the sum of the available items of that individual's peers/similar cohort. Both methods are very similar and seem to be the best method of interpreting missing data points.

Practical applications

All of this is great: But how does this apply to soccer and more specifically GPS collection?

So above we can see that there are very technical methods and algorithms in place to best replace missing data points within 'real world' scenarios but what can we take from this and apply to soccer and training load monitoring?

Positional and Team Based Averages

The most common issue for practitioners is poor heart rate traces in regard to data collection, so how can we use the methods described above to replace the data points to allow us to understand how the external load demands has affected an athletes internal response. Well if our data collection is structured correctly, we should be able to use previous data to make a best maximum likelihood replacement. This could be using collection drill-based data to understand how previous times a player has complete the specific drill they have responded to the stimulus. We could also use positional and team-based averages from that drill and create an average for this player. Even further to this if we have drill based data in metres per minute (m.min) format for metrics and then we could extrapolate the data to create a very likely replacement.

Further issues are 'GPS hasn't worked for either a training session or match' or 'The GPS stopped working 20 minutes prior to the end of the session'. In this case, like above it is about creating as close to a maximum likelihood estimate at what the data would have looked like. This could be via the use of previous match data against a similar standard opposition, positional averages, or by extrapolating data that we have got. In terms of a correction factor equation for games where the standard of opposition may be higher or the intensity of the game is higher that pervious times it may be worth trying to put an equation in place to best replace this (see section below). When the data has dropped off, we should still use the data we have collected but replace the missing data in the same way as mentioned above

How can we limit missing data points and what are best practices?

- Ensure practitioners switch on and off the GPS pods (not players)
- Check HR belts consistently in between drills
- Use Live feedback where possible

- Collect drill by drill GPS data
- Use positional averages within data collection
- *Are there any Algorithmns we can use?*

Reliability of the YoYo Intermittent endurance test level 2 (4 Minute submaximal version)

To ensure I was happy with the test that I was implementing to track the change in fitness within chapter 5 I wanted to run some reliability prior. This has been included within the appendices to allow the reader an understanding of the test itself.

Title: The reliability of the YoYo Intermittent Endurance Test Level 2 (4-Minute Submaximal version).

Introduction

The ability to repeat high intensity actions, such as sprinting and changing direction across a 90-minute game is primarily governed by a player's aerobic capacity. Consequently, it is the aerobic performance of soccer players that will determine whether they operate at elite or non-elite level from a physical perspective. In order to understand a player's aerobic capacity, it seems important to have the tools to accurately assess aerobic capacity in soccer players. It has become common within soccer for practitioners to conduct regular physiological assessments to assess this soccer specific endurance capacity, using versions and derivatives of the YoYo Intermittent running assessment. (Bradley et al., 2011; Krustrup et al., 2006). Research has focused on assessments that are maximal; The gold standard to assess aerobic capacity is via a lab-based VO2 max test however within a team-based setting where time is key there seems to be better methods to measure this ability. Furthermore, an incremental test lacks soccer specific movement such as change of direction which is important to understand due to the multi-directional nature of the sport. As a result of this a number of soccer specific field-based tests have been developed to try to represent the physiological profile of a soccer match such as the YoYo intermittent endurance test, level 1 and 2, along with the recovery-based YoYo test. In addition, some studies have started to focus on submaximal protocols, typically or 4 or 6 minutes in duration (Krustrup et al., 2006). As the slower running speeds and lower demands are stressed upon the players, practitioners can employ the testing procedure much more frequently allowing for increased accuracy of tracking changes in performance. Submaximal assessments have been shown to be reliable

(Doncaster et al., 2018; Owen et al., 2017) with the protocols modified by either duration or shuttle length.

Literature at present has used heart rate responses to the submaximal assessment to provide information regarding the physical status of players both during the exercise and post exercise cessation. (Krustrup et al., 2006; Owen et al., 2017). The main indication of a player's physical capacity as a result of a submaximal bout of exercise would be a reduction in HR at the end of the exercise (Buchheit et al., 2014) with large correlations seen in high intensity exercise performance. If an athletes HR recovers to a larger extent over a specific time period following the end of a standardised exercise period, conclusions can be made regarding the improvement in soccer specific endurance capacity. This can be useful for practitioners to allow for planning and full squad monitoring allowing for interventions to be implemented where necessary for players with less training or match exposure.

The physiological responses that are a result of the submaximal YoYo intermittent running tests can be used to provide a valid indicator of an individual's response to the same test when performed to exhaustion (Veulgers et al., 2016). In some cases, a practitioner may wish to use a different protocol for the assessment of both maximal and submaximal training status such as a 4 minute version of the test for some populations (Veulgers et al., 2016). With this in mind it is therefore important to understand how responses during assessments with shorter and pre-defined lengths relate to maximal performance in a range of protocols used amongst sub elite part time players, especially if their use enables a more time-efficient and less physically exhaustive method of assessing soccer specific endurance capacity.

As soccer specific capacity assessments are vital to understand physical status of their players it is also important that the assessments employed are time intensive and yield data that is both useable but does not alter the training schedule. For instance, it would be of benefit to practitioners to have a test that does not required a day off prior to testing and then again following the testing. Whilst this could be applicable in some full-time club settings, although not optimal, scheduling this for part time players is much more difficult; with the balance of obtaining objective physical data and the need for developing tactical and technical aspects of

the game imperative. It still is important to understand how effective specific training programs have been and therefore the notion of a shortened assessment protocol that are submaximal, do not require modifications to pre of post training loading and also directly relate to assessments that are maximal in nature may be an attractive proposition for applied practitioners. Therefore, the aim of this study was to determine the reliability of the 4 minute version of the YoYo Intermittent endurance test Level 2.

Methodology

Subjects

14 players within the under 18 squad, age: (16.5 ± 0.8) years; mass: 65.2 ± 7.8 kg; stature: 1.79 ± 8.5 cm; were involved in this study. All subjects had previous experience of physiological testing until volitional exhaustion, but none had previously performed the 4 min YYIET2.

Experimental Design

A repeated measures approach was used to investigate the reliability of physiological characteristics during the 4 minute version of the YYIET2. Subjects completed two 4 minute YYIET2 each separated by 3-5 days. Measures collected included HR.

Subjects attended a habituation session which was 48 hours prior to the first experimental trial during which anthropometry was also recorded. Subjects were then instructed to maintain their normal dietary habits during the study period. All the data collection was conducted on an indoor synthetic astro turf pitch. Each of the trials were preceded with 5 minutes of seated rest following which a resting HR was established. Subjects then performed 3 minutes of stretching and foam rolling followed by a standardized bike warm up.

Experimental Protocol

The protocol was identical for each test. The 4 min protocol was performed according to established guidelines described elsewhere. Subjects completed the initial 4 min (640m) of the YYIET2, which involved 40m shuttles with one 180 degree change of direction and included increased speeds (11.5km/hr start speed). After every 40m shuttle there was a brief active recovery of 5s duration where players had to go around a marker placed 2.5m behind the start line. After the 4 minutes was completed the players were asked to remain seated for the full duration of the recovery period. All participants will wear StatSports Apex GPS along with Polar H1 heart rate belts to allow for heart rate throughout the test to be analysed.

Heart Rate & Global Positioning System

On all testing occasions HR was recorded from the start of the warm-up to 5 minutes following the cessation of the recovery period. HR was analysed on the StatSports Apex software. Peak heart rate was the highest heart rate recorded during the test, on the condition that players performed the maximum. HR during the 4 min YYIET2 was calculated as the maximal HR of the last 30s before the 4 minute time point and was shown as a relative (percentage HR maximum) values. Depending on exercise intensity 3-4 mins of exercise is generally required to reach steady state, therefore this is why HR at 4 minute was assessed.

Results

Descriptive statistics are reported as mean ± SD. Statistical analyses were performed using SPSS software (version 26.0, IBM Corp., Arnock, NY, USA). To investigate the reliability of the 4 min YYIE2, Intra class correlation coefficient (ICC) and typical error (TE) were determined for trial 1 vs trial 2. The smallest worthwhile change (SWC) was also investigated as 0.2 x the between subject SD.

4-minute YYIE2

Heart rate data is presented in table 2. All players completed the total distance for both 4 minute YYIE2 trials. HR measures at 4 minutes (ICC: 0.78, CV: 1.7). In addition, mean HR for

test 1 was 82.5% and for test 2 81.5% respectively (diff 1%).

Figure 8.2 Correlation for Maximal Heart rate in submaximal YoYo Intermittent endurance test level 2.

Table 8.6 Reliability of Physiological responses during recovery following the 6 min YYIET2. ICC = intra-class correlation coefficient; TE = Typical error; CV = coefficient of variation; SWC = †absolute difference between heart rate at 4 min

	Heart rate at 4 minutes
Trial 1 (mean ± SD)	**82.5 % ± 0.8 %**
Trial 2 (mean ± SD)	**81.5 ± 1.3 %**
Change in mean (trial 1 vs 2)	**1.0 %**
ICC	**0.78**
TE	**1.4**
CV	**0.6**
SWC	**0.64**

The aim of this study was to determine the reliability of the 4 min YYIET2. Our data, in agreement with data previously reported during submaximal assessments demonstrated that

HR responses during the 4 min YYIET2 are reliable measure and appropriate for use within sub -elite part time soccer players.

CHAPTER NINE

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