

Physical testing and monitoring practices in elite male football

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OVERVIEW

There is limited published research on strength and conditioning (S&C) practices in elite football. Information regarding athlete testing and monitoring practices would be valuable for both applied practitioners and researchers investigating practices in professional football. The aim of this study was therefore to detail the current testing and monitoring procedures of practitioners working in senior male football.

A questionnaire was developed that comprised the following five sections: 1) why do you use testing and monitoring practices?; 2) what variables are tested during the separate pre-season and in-season phases?; 3) how often are variables tested or monitored?; 4) what is the impact and level of effectiveness of monitoring strategies?; and 5) what are considered the markers of a successful programme? Fifty-one (51 men; age 32.45 ± 7.27 years) out of 74 (68.9%) coaches responded to the questionnaire, all of them working in senior male football for 9.61 ± 5.65 years. All respondents reported using some testing and monitoring practices with the aim of improving performance ($n=43$, 84%) and prevention of injury ($n=42$, 82%). Each team assesses a mean of 9.7 variables during the in-season phase. The majority of practitioners will regularly monitor body composition (86%), training load via GPS data (82%) and heart rate response (74%), player wellness (72%) and lower limb power via CMJ (59%). Athlete feedback and injury rate were seen as the biggest determinants of successful S&C programming. This survey represents new data regarding testing and monitoring practices in elite male football and as such serves as a review of applied information.

Introduction

Physical performance testing is an integral component of an elite football player's development programme.^{2,4,27} The key role of a strength and conditioning (S&C) coach is to help improve physical performance and reduce injury rate.⁶ Although designing training programmes appears to be the first step of training management, monitoring the

impact of the sessions on players appears to be the second important step towards being successful in the training process.¹³ As part of the efforts to maximise performance and minimise injury occurrence, S&C coaches and medical staff will frequently engage in multi-dimensional strategies aimed at the monitoring of player wellness, training load, physical status, strength and readiness to train on a daily basis.^{30,48}

Athlete monitoring and training load management has long been a key responsibility for S&C and medical staff.¹⁸ Over the past decade, the emphasis on athlete monitoring in elite sport has risen exponentially, largely from the desire to achieve and maintain performance and mitigate injury risk. Such performance assessments offer an opportunity to evaluate a player's physical qualities, and the derived information can be used to provide coaches and practitioners with evidence to guide talent identification, player selection and developmental programming.¹² Historically, athlete load management relied on coaches' observations. As new technologies for measuring athlete training dose and response surfaced (eg, heart rate monitoring and GPS tracking), the desire to harness and embrace these technologies proliferated their use in S&C, sport science and medical disciplines.¹⁸

Although improvements in technology such as GPS have allowed the monitoring of training load in greater detail, there are now many variables available with the aim of determining overall training load. In a recent report, Akenhead and Nassis¹ surveyed practitioners working within professional football clubs across the world regarding their implementation of training load management. In total, 56 different training load variables were identified, with teams recording 7 ± 2 variables for training session, and 3 ± 2 variables for competitive matches. Understanding how many and which variables to monitor, and how frequently to monitor is important when trying to decide on the athlete's response to a given training load. Modification of training volume and intensity of both pitch- and gym-based loading (ie, the overall load), throughout periods of the season would help optimise physical performance, reduce accumulation of fatigue and decrease the risk of injury.

Aside from GPS tracking, other common measures associated with player readiness include biomedical markers of stress (eg, creatine kinase;³⁴ salivary immunoglobulin A (IgA),³⁷ jump performance,⁴⁸ lower limb strength,^{29,42} fatigue,⁴⁸ and subjective evaluations such as session rating of perceived exertion (sRPE).¹⁹

Although research has shown how monitoring one measure can highlight an athlete's training response or readiness, it is currently unknown what – and how frequently – assessments are used within the elite football environment. In addition, it is also unknown if assessments of performance

such as speed, muscle strength, change of direction or aerobic capacity are tested throughout the season.

Ultimately, the overall aim of any monitoring process should be to provide information to help maintain player performance and availability for competition.^{7,20} Given that physical performance assessments are used to inform decision making throughout the player development process,⁴⁵ robust interpretation of test performance data is, therefore, paramount.⁵ To date, there is no information available that asks practitioners for their opinions on the usefulness of their monitoring data, and if their processes are deemed reliable, informative and valid.

Although physical performance testing and monitoring processes have been examined in many other professional sports such as basketball,⁴³ ice hockey,¹⁶ American football,¹⁵ rugby union,²⁵ rowing²² and cricket,³⁹ there is limited data available detailing what processes occur in elite football. Additionally, there is no data that exists detailing the frequency of testing assessments, the reasons why such assessments are employed, or what contributes to a successful programme. Therefore, the aims of this research were:

1. To document what testing and monitoring processes occur in professional senior football environments
2. To ask practitioners if the testing and monitoring procedures used actually create an impactful change in performance or practice
3. To question the frequency that testing and monitoring assessments occur during a season
4. To provide new evidence that practitioners in professional football can use to review current practices and also provide new ideas for diversifying/modifying future practices
5. To provide a beneficial resource for football practitioners similar to other sports that can inform coaches for future practice or research

Methods

EXPERIMENTAL APPROACH TO THE PROBLEM

This study utilised a quantitative research design in the form of an online survey to examine the current practices and

perceptions of S&C in senior male football clubs in the UK and USA. The survey, 'Strength and Conditioning Questionnaire', was adapted from that commonly used in other sports by Ebben and Blackard.¹⁵ The questionnaire was adapted to be specific to football and to the demands of this research and to test the hypothesis that football S&C coaches follow contemporary, scientifically based principles of S&C. It was hoped that coaches would be willing to share their ideas, practices and perceptions through this survey.

SURVEY

The questionnaire was pilot-tested on a group of five strength and conditioning coaches, academics and researchers to determine the reliability and validity of the questions. Once feedback was received, certain questions were modified. This included changing the order of the questions, so that the logical order would be improved, changing some qualitative questions to quantitative queries and rewording questions to make them more comprehensive. After this, the survey was reassessed by a supervisory panel before being sent to the coaches.

The survey consisted of the following five sections: 1) why do you use testing and monitoring practices?; 2) what variables are tested during the separate pre-season and in-season phases?; 3) how often are variables tested or monitored?; 4) What is the impact and level of effectiveness of monitoring strategies?; and 5) what are considered the markers of a successful programme?

The survey contained seven questions relating to the objectives of the research. It was an online survey, and it was distributed to S&C coaches, sports scientists and medical professionals working in professional senior male football teams in the UK and America via the website sogosurvey.com.

DATA COLLECTION

All subjects were informed of the purposes of the investigation before participating in the study: an initial email or message via social media platforms describing the study was sent to S&C coaches at selected football clubs. This message included a description of the broader study, and an explanation of

what the survey would entail. Only those who responded were contacted at a later date, via an email containing an electronic link to access the survey.

The coaches were given 30 days from the time of receiving the email to complete the survey. If no responses were received after 30 days, a reminder was sent for a further 30 days. After 60 days, the questionnaires that were completed were collated for statistical analyses. All data were collected between July and August 2019, with reference to the 2018-19 football season.

STATISTICAL ANALYSIS

All data were collected using an online questionnaire (sogosurvey.com, VA, USA). The survey consisted of a combination of fixed-response and open-ended questions. Data analysis procedures were descriptive in nature with frequency counts and percentages calculated. In addition, some of the questions were scored to produce rank scores, with the frequency count of each response reported, as well as a 5-point Likert Scale set as 1 (not at all) to 5 (very important).

Results

PERSONAL DETAILS

Fifty-one (51 men; age 32.45 ± 7.27 years) of 74 (68.9%) coaches responded to the questionnaire. The respondents consisted of three head S&C coaches, twelve heads of sports science, six heads of performance, eight heads of fitness and one head of medical. Four senior S&C coaches, one senior sports scientist, three first team S&C coaches, five first team sport scientists, one first team physiotherapist, three first team rehab specialists and one assistant S&C coach also responded. Two responders were highlighted as 'other', but no further information was given.

Out of the 51 responders, 45 (88.2%) practitioners were based in the UK, and 6 (11.8%) in the USA. The league levels that the participants worked in are presented in Table 1. On average, participants had been working in professional football for 9.61 ± 5.65 years and had worked in their current role for 2.97 ± 2.79 years.

Table 1. Level of league worked in by coaches who responded

PREMIER LEAGUE	CHAMPIONSHIP	LEAGUE ONE	LEAGUE TWO	NATIONAL LEAGUE	SCOTTISH PREMIERSHIP	MAJOR LEAGUE SOCCER
9	17	8	7	2	3	6

'it is currently unknown what – and how frequently – assessments are used within the elite football environment'

PHYSICAL TESTING AND MONITORING

Why?

The first question asked why practitioners included testing and monitoring processes, with responses highlighted in Figure 1. The most common response was to 'improve performance' (n=42), 'prevent injury' (n=41), and to 'manage training load' (n=39). Two coaches provided additional feedback, stating that they helped 'provide baseline data for rehab/return to play', and to 'monitor the recovery process and readiness to train'.

What?

The second question asked what variables were tested during the pre-season phase, with responses highlighted in Figure 2. The most common response was 'body composition' (n=44), 'CMJ' (n=39), and 'cardiac screening' (n=37). Eight coaches answered 'other' and provided additional feedback, stating 'sit-and reach', 'MAS runs', and 'sub-max runs' were tested. The third question asked what variables were tested during the in-season phase, with responses highlighted in Figure 3. The most common response was 'body composition' and 'GPS – post session' (both n=41), and 'GPS – live feed' (n=38).

How often?

In this sub-section, coaches were asked how often testing and monitoring procedures were undertaken throughout the season. When asked how often the players were formally tested for acceleration during the season, the most common response from practitioners was 'never' (n=17). Seven coaches specifically test acceleration at 'the start of pre-season only', and six said 'during international breaks' and at the 'end of each periodisation block'.

When asked how often the players were formally tested for agility or change of direction during the season, the most common response from practitioners was 'never' (n=24). Seven coaches specifically test change of direction at the 'end of each periodisation block', and five 'during international breaks'. When asked how often the players were formally tested for anaerobic capacity during the season, the most common response from practitioners was 'never' (n=20). Six coaches specifically tested anaerobic capacity at the 'start of pre-season only', and 'during international breaks'.

When asked how often the players were formally tested for body composition during the season, the most common response from practitioners was 'monthly' (n=33). Six

coaches specifically test body composition 'every other month', and five at the 'end of each periodisation block'. When asked how often the players were formally tested for cardiovascular endurance during the season, the most common response from practitioners was 'on international breaks' (n=11). Ten coaches specifically tested cardiovascular endurance at the 'start of pre-season' only, and five at "start and end of pre-season, plus the end of the season".

When asked how often the players were formally tested for flexibility during the season, the most common response from practitioners was 'never' (n=16). One coach specifically tested flexibility 'weekly', and six 'at the start of pre-season only'. When asked how often the players were formally tested for muscular endurance during the season, the most common response from practitioners was 'never' (n=22). Five coaches specifically tested muscular endurance 'during international breaks'.

When asked how often the players were formally tested for muscle power during the season, the most common response from practitioners was 'at the end of each periodisation block', 'monthly' and 'never' (n=9).

When asked how often the players were formally tested for muscular strength during the season, the most common response from practitioners was 'never' (n=12). Ten coaches specifically tested muscular strength at the 'end of each periodisation block', and five tested 'weekly'.

Impact

The next sub-section asked coaches if their testing and monitoring procedures helped to form a meaningful change in their decision-making process. Here coaches provided more than one answer. A total of 23 out of the 51 (45%) coaches stated that 'all testing and monitoring procedures provide part of an answer to help inform our decision'. Twenty-two (43%) coaches responded that: 'the majority of testing and monitoring provided part of an answer to help inform our decision', and 13 (25%) coaches stated: 'as a sport science and medical team we like to use this data, but senior management isn't always willing to change training structure based on our results'. Four practitioners stated that 'only some of our testing helps us inform our decisions', and two stated that 'not much of the data is used to force meaningful changes in our actions'. One respondent gave a more detailed answer that 'all testing has a purpose, not all testing

changes implementation for all players though. Senior management have the right to decide which bits of information they want to act upon based on recommendations on an individual basis'.

Accuracy and reliability

Coaches were asked if they believed that their testing markers were accurate, reliable and validated in order to determine the success or failure of the programme. A total of 36 (71%) coaches replied 'yes', whereas 11 stated that 'no', they did not believe their testing markers to be accurate. Five coaches gave more detailed answers, which included 'not in all cases'; that 'all testing is statistically flawed in the applied environments and we accept that. Validity and reliability enables us to determine how useful, not how significant a test can be'; that holes had been 'found in all the data'; that 'too many other factors determine the success or failure of a programme'; and finally that 'we've tried our best to generate our own reliability and validity data for all our assessments'.

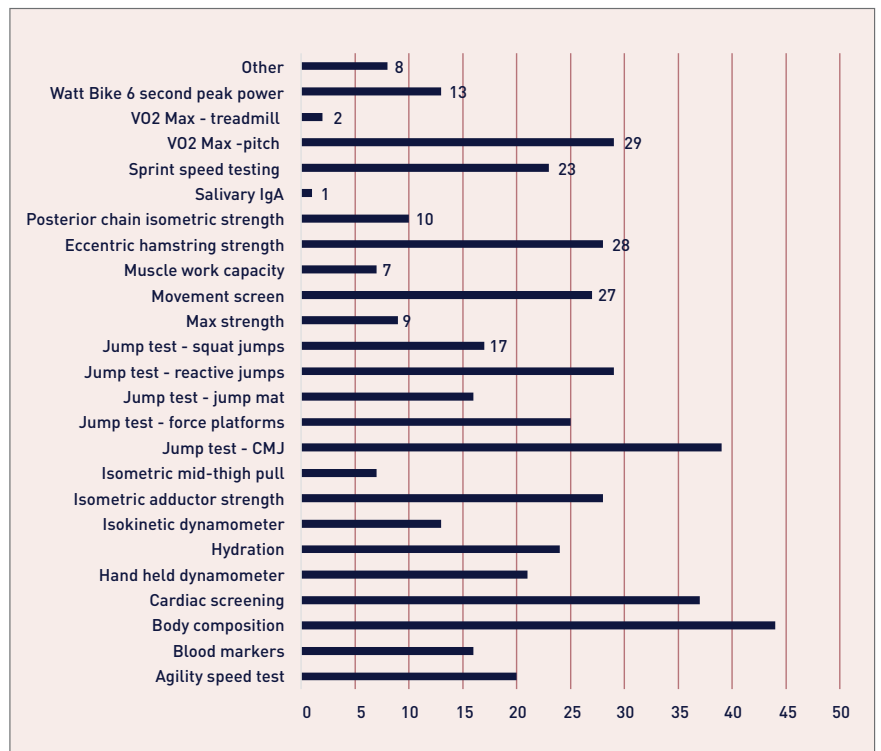
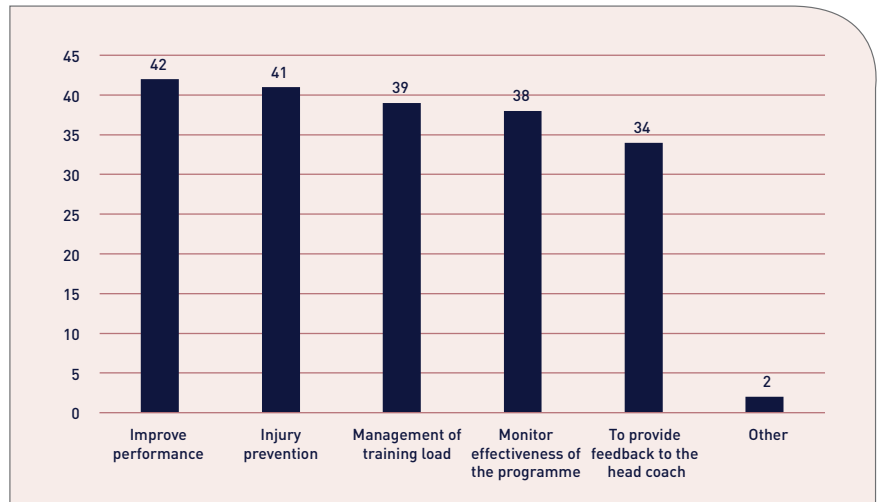
Markers of success

The final question in this sub-section on testing and monitoring asked practitioners what markers or measures the coaches used to determine the success or failure of the S&C programme. The most common response was 'athlete feedback' (n=42), 'injury rate' (n=40), and 'gym performance' (n=38). Figure 4 highlights coaches' responses.

Discussion

The present study sought to conduct a comprehensive survey of strength and conditioning testing and monitoring practices in senior professional male football. To the authors' knowledge, this is the first assessment of testing and monitoring in senior professional male football that highlights the frequency of assessments and the practitioners' opinions on what defines successful strength and conditioning practices. It also expands on the current research into testing and monitoring practices in football.^{1,30}

The original findings in this research are that practitioners will test and monitor their players to improve performance, prevent injury risk and manage training load. Results highlight that there is no universally adopted monitoring approach within professional football, although many clubs do adopt similar practices. The majority of practitioners will regularly monitor body



composition, training load via GPS data (both 82%) and heart rate response (74%), player wellness (72%) and lower limb power via CMJ (59%).

Assessment of body composition was the most frequently used test to assess the players during the pre-season period, with body composition and GPS tracking most common during the in-season as well. However, in-season testing of physical performance such as speed, change of direction and muscular strength was most commonly 'never' assessed.

Most coaches valued athlete feedback as the biggest determinant of a successful strength and conditioning programme ahead of any other indicator.

Figure 1 (top):

Reasons why coaches use testing and monitoring procedures

Figure 2 (bottom):

Most commonly used testing variables measured in pre-season testing

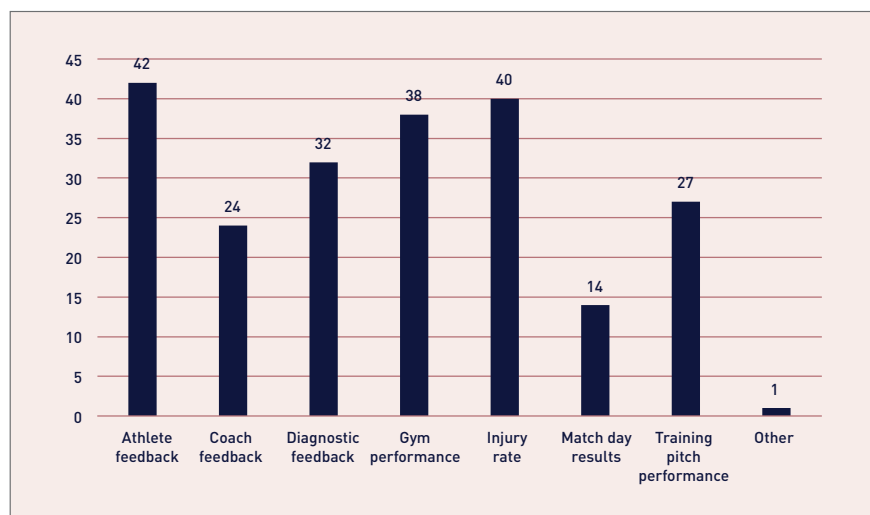
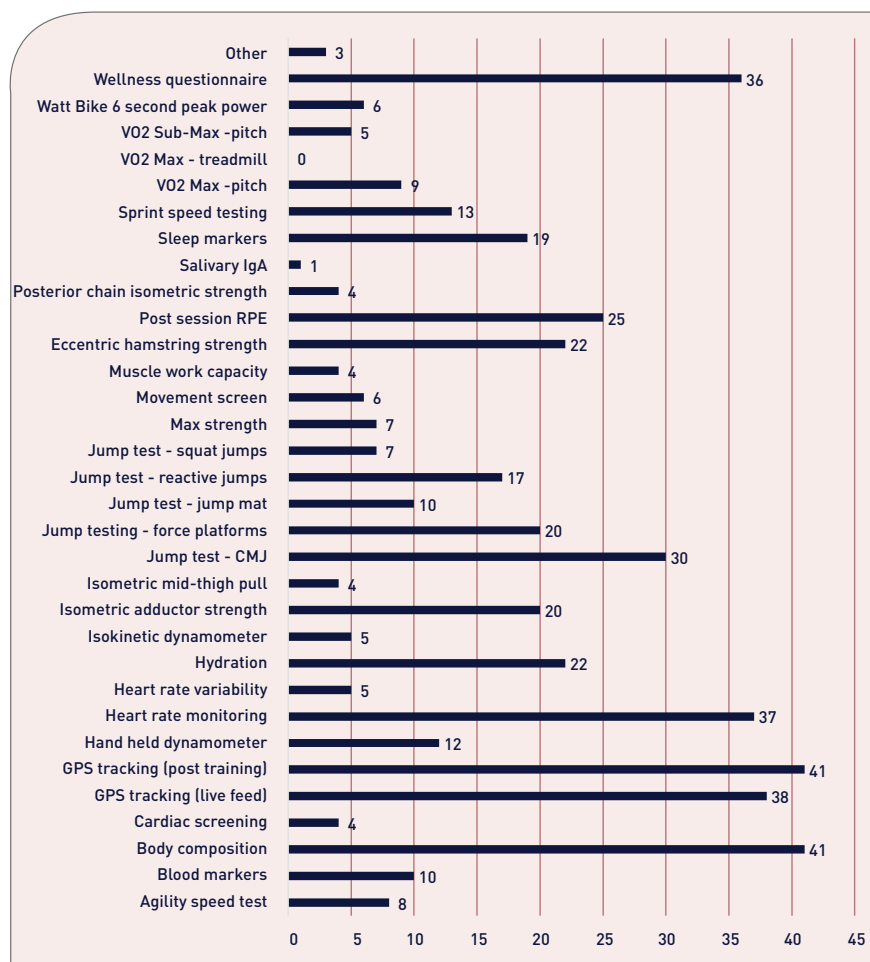


Figure 3 (top). Most commonly used testing and monitoring variables measured in-season

Figure 4 (bottom): Markers and measures used to determine the success or failure of strength and conditioning programmes

Seventy-four practitioners working in professional, senior male football were invited to participate with 51 responding (69%). Although this may be lower than some previous response rates within similar studies in other sports (47-87%), this is the highest number of respondents obtained in a study examining S&C provision in a single sport to date. Previous studies examining S&C practices in various sports have received between 20 and 43 responses.^{15,16,22,25,43}

In similar reports into injury rates in professional football, response rates were 44,³⁰ and 32.³¹ Also in football, Akenhead and Nassisi¹ had a 50% response rate for 41 coaches regarding training load practices. As such, 51 responses at a return rate of 69% was deemed sufficient for analysis and is the highest number of respondents to a survey of S&C practices, especially in elite football.

All respondents supported athletes in professional, senior male football. There were nine respondents from the English Premier league, 17 from the English Championship, eight from League One, seven from League Two, three from Scottish Premiership; there were also six from Major League Football and two from the National League in the US. Therefore, the data presented in this article are reflective of elite, senior male football.

Respondents were also experienced in the field of S&C, with an average time spent working in football of 9.61 ± 5.65 years; furthermore, they had worked in their current role for 2.97 ± 2.79 years. This level of experience is similar to those coaches who responded in similar research in different sports.^{15,16}

Testing and monitoring

Physical performance testing is an integral component of an elite football players development programme^{24,27} and has shown to be considered important by practitioners in this survey.

Testing and monitoring procedures were incorporated by all practitioners who responded to this survey. This may not be surprising because testing is thought to be useful in identifying team and individual strength and weaknesses; it also helps in goal setting and can be used to assess and demonstrate the efficacy of the programme.⁴⁷ In comparison with other studies in football, McCall et al³⁰ showed that 100% of clubs tested for injury risk during pre-season, 81.2% in-season and 40.9% at the end of the season. Although the McCall study³⁰ highlighted some strategies used within football, the current report involved a greater depth of questions, aimed to investigate the type of testing used, when it was administered and how often.

In this report, on average, each team tests or monitors 9.8 variables during the pre-season screening phase (total number of answers, 502, divided by 51 respondents), and 9.7 during the season. In a recent review by Drust,¹⁴ the number of testing and monitoring 'touch points' between staff and

a Premier League player can range from 3 – 7 per day.

In terms of training load monitoring alone, Akenhead and Nassis¹ found that practitioners recorded 7 ± 2 variables when monitoring for training load. This can include readiness to train measurements, field-based monitoring, gym-based monitoring, recovery protocols, match performance evaluation, medical screening and nutritional supplements. This study does not detail the exact tests used, but highlights the amount and range of monitoring processes players have to adhere to per day or week. These results are similar to those previously reported in other sports including Major League Baseball (MLB) (3–4 aspects), National Football League (NFL) (9–10 aspects), National Hockey League (NHL) and National Basketball Association (NBA) (7–8 aspects), rowing (4–5 aspects) and rugby union (11 aspects).

However, comparisons should perhaps be interpreted with caution as the S&C practices in a number of these sports were reported in a period between 2001 and 2005 and it is very likely that assessment batteries in NFL, NBA, NHL and MLB have progressed and been adapted over the past 18 years. Comparisons should also be made with caution as participants in this current study were allowed to select answers from a more comprehensive list of 25 aspects, whereas in many other studies they are restricted to 10–11 options. For example, in rugby union,²⁵ coaches were only able to select a global term of ‘muscle strength testing’, whereas in this current research strength testing options were offered in more detail such as ‘isometric mid-thigh pull’, ‘max strength test’, ‘eccentric hamstring strength’ or ‘posterior chain isometric strength’. This was because the current authors felt it would give a far greater understanding to the types of tests employed in professional football.

WHY DO WE MONITOR?

The most common reason for including testing and monitoring processes was to improve performance ($n=43$, 84%) and injury prevention ($n=42$, 82%), which is in agreement with previous research.¹ In addition, in the first part of this review,⁶ S&C practitioners focus their programming on increasing performance and reducing injury rates. Therefore, it is not surprising that procedures are put in place to monitor these training goals.

Other common answers as to why coaches tested players were ‘management of

training load’ ($n=40$, 78%), and to ‘monitor effectiveness of the programme’ ($n=39$, 76%). Two coaches provided additional feedback, stating that they helped ‘provide baseline data for rehab/return to play’, and to ‘monitor the recovery process and readiness to train’. Monitoring an athlete’s ‘readiness to train’ has previously been shown to be a useful tool in professional, elite football players.⁴⁸ This process may involve subjective questionnaires to assess fatigue, sleep quality, delayed onset of muscle soreness (DOMS) and session rating of perceived exertion (s-RPE), as well as heart rate variability and post-exercise heart rate recovery.⁴⁸ In previous research in football and other high-performance sports, it has been shown that over half the practitioners use self-reported measures daily to monitor well-being of the athletes.^{1,47} Subjective measures have been shown to highlight early risk factors of over-training in athletes before there is a notable drop-off in performance,⁷ and as such can be seen as a useful tool to assess player training status.

WHAT DO WE MONITOR?

Pre-season monitoring

The pre-season period is often considered to be the principal opportunity for physical preparation in team sports.^{3,11} As such, practitioners will often collect a large amount of physical screening data that helps with the understanding of the players’ physical attributes, injury risk factors and readiness to train to help create group or individual training plans for the forthcoming season.

During pre-season, the most frequently used testing and monitoring tools were body composition testing ($n=44$, 86%), followed by counter-movement jump (CMJ) testing ($n=40$, 78%) and cardiac screening ($n=38$, 74%).

In relation to studies in other sports, vertical or CMJ height is also the most commonly used measure of lower limb muscular power.^{25,43} Pre- and post-event jump height may provide valuable data in relation to exercise intensity and athlete neuro-muscular fatigue.^{28,33} Immediate post-exercise performance reductions are associated with maximal exertions in individual sports, which include repeated vertical jumps and also non-weight-bearing sports such as cycling.⁹ CMJ have a high test-retest reliability score compared with the squat jump and depth jump and is the most valid test for the approximation of explosive power of the lower limbs.^{28,40} The CMJ has also been shown to have high

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‘Heart rate monitoring was the second most used monitoring tool ... it remains a valuable tool ... to measure the internal response of a player’

correlations to 1-rep-max squat strength, speed and agility,^{36,38} and as such it could be argued that only CMJ needs to be monitored, as changes in this variable are possibly indicative of changes in other. Like body composition testing, the CMJ is relatively non-invasive and time-consuming, and as such is a useful marker of physical performance changes throughout the season.

Other common answers were ‘on pitch VO₂ Max testing, such as bleep test, yo-yo or 30-15’ and ‘reactive jumps’ (n=30, 58%), ‘eccentric hamstring strength’ and ‘isometric groin strength’ (n=29, 56%) and a ‘functional movement screen’ (n=28, 54%). Eight coaches responded with ‘other’: these answers included ‘sit-and reach’, ‘MAS runs’, and ‘sub-max runs’.

In-season monitoring

The most common markers monitored in-season were body composition and post session GPS tracking, with 42 out of 51 coaches (82%) using these regularly. GPS tracking - live feed (n=38, 75%), heart rate monitoring (n=38, 74%), wellness questionnaires (n=36, 72%), and counter movement jump testing (n = 30, 59%), were ranked 2nd, 3rd, 4th and 5th accordingly.

As management of training load was reported by 78% of coaches (n= 40) as being the reason why they tested players, the high number of coaches using GPS tracking devices to monitor training is no surprise. The application of GPS tracking devices has provided new insights into both the nature and the intensity of the actions that make up the activities in football training and match play, to determine the overall training load for a squad or individual player.³⁵ This has allowed practitioners and researchers to think about the ‘loads’ associated with these actions in a more sophisticated way than ever before, so it is of no surprise that they are widely used in football practice²⁶ and in return to play protocols.⁴⁶ These findings are supported by McCall et al,³¹ who showed that tracking of minutes played and intensity of work with GPS, along with heart rate monitoring, was one of the most commonly used monitoring tools used by practitioners during the 2014 FIFA World Cup.

In the current study, heart rate monitoring was the second most used monitoring tool, with 74% of coaches (n= 38) using it daily. Heart rate monitors are an accessible and non-invasive tool:⁴⁴ data is used to give an indication of the physiological or cardiovascular response of the activity and frequently supplements the movement data collected by practitioners via GPS tracking during training. Despite its limitations in providing an indication of the cardiovascular response to high-intensity intermittent exercises, it remains a valuable tool for the majority of practitioners to measure the internal response of a player.²⁶

How often do we monitor?

As previously mentioned, S&C coaches are utilising testing and monitoring processes to improve performance and injury prevention. Although not specifically referenced in this report, the high number of coaches using GPS to monitor training load would suggest that these devices are used daily in relation to training sessions with the aim of managing training load.

Lower limb power was tested with varying degrees of frequency, with the most common response from practitioners being ‘end of each periodisation block’, ‘monthly’ and ‘never’ (n=9). Three (5.8%) coaches also tested weekly, monthly or every other month. CMJ was the 2nd and 5th most frequently tested performance marker administered during the pre-season and in-season phases respectively. CMJ is the most valid test for the approximation of explosive power of the lower limbs^{28,40} and is also the

most commonly used measure of lower limb muscular power in other team sports.^{16,25} In addition, CMJ is relatively non-invasive and time-consuming, and as such could be a useful marker of physical performance and neuro-muscular fatigue changes throughout the season.⁴⁸

In the current study, body composition was tested 'monthly' by 33 of the coaches and thus more frequently than all other markers of physical performance. Body composition is the most commonly tested physical marker, with 86% (n=44) and 80% (n=41) of coaches conducting this test during pre-season and the in-season respectively, suggesting that this is seen as a key performance indicator by key decision makers at the various clubs. In other sports, body composition is tested just as frequently during the season, with between 83-100% coaches testing.^{15,16,22,25,43} A higher lean muscle mass, and low body fat/adiposity in national level football players has been shown to be associated with power-related qualities and repeated sprint ability⁸ and total distance covered during match play.⁴¹ In addition, Arnason et al⁴ reported a positive linear relationship between CMJ, leg power, percent body fat, and team success. Results showed that teams with higher fitness levels and lower percent body fat had a higher league ranking. Monitoring body composition may also be useful for assessing any gains in lean mass following any prescribed resistance type training.

It has previously been shown that a high proportion of practitioners in professional football specifically target speed qualities such as acceleration, max speed and change of direction speed at least once a week during training sessions.⁶ However, when asked how frequently these performance markers, in addition to anaerobic capacity, muscular strength and muscular endurance were tested, the most common answer given was 'never'. This does suggest a lack of consistency between the stated performance goals and the methodologies deployed, as these speed and strength qualities are considered important in the sport and have been previously recommended in the literature.⁴

These findings are similar to those reported in other studies in football,³⁰ where, despite fatigue and fitness being identified as the top risk factor for injury, only 27% (n = 12) of teams tested the associated physical capabilities. Similarly, in the same study although muscle imbalance was identified as the third most important risk factor, only

41% (n=18) of teams used strength tests in their testing protocol. In other sports, such as NHL¹⁶ and NBA,⁴³ this is also a consistent trend. In basketball, acceleration was the least tested physical variable, and in ice hockey, only 30% tested speed, acceleration or agility despite 95% frequently training these speed qualities.^{16,43} It appears that coaches will frequently target training these performance skills, but may test these qualities far less frequently.

Despite the most common answer for testing muscular strength being 'never' (n=12, 23.5%), a number of coaches (n=10, 19.6%) tested at the end of each periodisation block, or during international breaks (n=4, 7.8%). Although not questioned, each periodisation block could be as often as every 4-6 weeks, and at times, international breaks occur at the same time intervals. If this is the case, then strength testing may actually occur more frequently than initially perceived. International breaks correspond to non-playing weeks for the majority of the clubs surveyed so this would allow for a more suitable time to administer these tests rather than during periods of fixture congestion.

These results are in contrast to those in rugby union, where max speed and power (both 88% of coaches), acceleration and max strength (both 86% of coaches) are the most frequently tested indices.²⁵ The notable

'In order for the S&C coach to influence change, coach buy-in and effective communication are essential'



‘Ultimately, the effectiveness of monitoring is determined by the quality of decisions that arise from it and their impacts’

difference may be due to the perceived differences in physical qualities required in rugby union and football. In rugby union, 41 of the 42 teams, and 38 of the 42 teams test in pre-season and in-season accordingly.²⁵ However, it is not specifically reported as to how frequently or what measures are taken during the in-season phase, just if testing does take place.

Reasons for the lack of testing of performance markers such as acceleration, change of direction, anaerobic capacity, muscular strength and muscular endurance were not asked in this survey; but it could be suggested that lack of equipment, number of staff, priority in the training week and congested fixture scheduling are all reasons as to why they are not frequently or ever monitored, as these are often reported barriers to the implementation of S&C practices.^{1,6,10,26,50} In comparison, body composition testing can be quick, non-invasive and easy to administer within a training day, regardless of fixture scheduling, and as such practitioners may feel it a suitable marker for performance status. In reality, and despite the significant advances in sport science, whereby tests can be administered quicker, and where the knowledge base has grown exponentially, time still remains very limited during the season for a number of reasons. For example, conducting maximal fitness tests (speed, strength etc) may not be deemed appropriate during a season where football teams often play two games per week

for consistent periods of time. Therefore, any fitness testing that is conducted, with the possible exception of pre-season, must be streamlined and strategically implemented.

Impact and level of effectiveness of monitoring strategies

The aim of collecting physical performance data is to facilitate evidence-based decision making on overall training load prescription. Ultimately, the effectiveness of monitoring is determined by the quality of decisions that arise from it and their impacts.

Practitioners were asked if their testing and monitoring procedures helped form a meaningful change in their decision-making process. Coaches were able to answer more than one option. Twenty-three (45%) out of the 51 coaches state that ‘all testing and monitoring procedures provide part of an answer to help inform our decision’. Twenty-two (43%) coaches responded that ‘the majority of testing and monitoring provide part of an answer to help inform our decision’, and 13 (25%) coaches stated that ‘as a sport science and medical team we like to use this data, but senior management isn’t always willing to change training structure based on our results’. One respondent gave a more detailed answer that ‘all testing has a purpose, not all testing changes implementation for all player through. Senior management have the right to decide which bits of information they want to act upon based on recommendations on an individual basis’.

This information should be seen as important for the developing practitioner to consider: the data you collect may be important to you but understanding that the manager makes the overall decision is key. Coach buy-in can be seen as a barrier to implementing any data-driven decisions.¹ In many cases it is the head coach/manager who dictates the training programme and therefore determines a large part of the TL. In order for the S&C coach to influence change, coach buy-in and effective communication are essential. Practitioners must have an understanding of the coaches’ view on sports science/strength and conditioning and its place in the overall process.

Four practitioners stated that ‘only some of our testing helps us inform our decisions’, and two said that ‘not much of the data is used to force meaningful changes in our actions’.

Coaches were also asked if they believed that their testing markers are accurate, reliable



and validated to determine the success or failure of the programme. Thirty-six (71%) of coaches said 'yes', while 11 (22%) stated that 'no' they did not believe their testing markers to be accurate. Unfortunately, practitioners were not asked if any in-house reliability tests were performed to understand the significance of their testing results. However, some practitioners gave further responses stating: 'we've tried our best to generate our own reliability and validity for all our assessments'; that 'all testing is statistically flawed in the applied environment and we accept that', and that 'too many other factors determine the success or failure of a programme'.

In support of some of these responses, research from Akenhead and Nassisi¹ suggests that there may be a gap between the expected and perceived actual effectiveness of testing and monitoring at preventing injuries and improving performance. In addition, Carling et al¹⁰ stated that the limitations of tools and protocols combined with concerns relating to the real-world meaningfulness of data, their interpretation and practical application through subsequent interventions are key issues in professional football.

It has been reported that 40% of testing and monitoring procedures are currently limited by methodological or theoretical considerations in professional football.¹ Practitioners also reported that poor validity and reliability of assessments represented a barrier to effective practice. Although the same level of limitations were not reported in this current study, these potential problems may be some of the reasons preventing the widespread application of recommended testing procedures among practitioners. As a consequence of no gold standard measure of football performance, testing and monitoring in football would seem to be not completely driven by the principles of science, but by a subjective individual belief in systems developed through experience and the limitations of the 'real world' working environment. This however, may not be too problematic as research science has yet to understand many well-practiced strategies that are common in many environments.

To identify if a 'true change' in a measure of physical performance has occurred due to a specific stimulus, an understanding of the minimal detectable change in that measure is required.⁴⁹ The seemingly low use of such analyses in the club setting may be related to a lack of awareness of the statistical methods, insufficient experience

in implementing the method, or perhaps a lack of time and human resources.¹ Clubs and practitioners seeking to enhance the meaning and usefulness of their data may wish to familiarise themselves with these methods or seek outside expertise to assist with this process.

What is apparent is that – although testing and monitoring is common – its impact on practice is less clear and there remains a level of doubt about the full impact of this work.

Determinants of success

The impact of strength and conditioning programming on certain performance markers such as speed, strength, jump height is often reported.^{2,21,32} The novel finding in this study is the reporting of what coaches believe to be the determinants of a successful strength and conditioning programme.

Programme or coaching success could easily be measured by match day performance/ results. For example, a successful team is likely to be driven by a successful coach/ manager /coaching setup. Success or failure of a head sports coach/ manager is often viewed almost entirely on won vs. loss records. Too many times, the S&C coach can be part of the 'too much credit' and 'too much blame' syndrome that is persistent in coaching.²³ Interestingly, actual sporting performance whether that be in training, (n= 27, 53%) or match day performance (n= 14, 27%) was ranked at the bottom of the coach's determinants of successful programming in this survey.

Although successful match day performance especially is reliant on a multitude of variables, it could be considered surprising that sport performance was the lowest ranked response within the coaches surveyed. There are strong links between S&C programming and key performance indicators in many sports,^{2,11,21,25,32} so it may be amiss not to judge overall programme success on team performance, whether that be actual results or parameters of fitness for example. Conversely, it could be argued that a S&C practitioner's job is not to win matches, but to provide the head coach/manager with the players who are most suitably prepared for each match, for the duration of the season. It would then be the managers' responsibility to select the players, relay tactics, team set-up and instructions for the match itself.

Although match day performance was ranked at the bottom, athlete feedback was

'research science has yet to understand many well-practiced strategies that are common in many environments'

'As coaches, we could be in danger of focusing on athlete happiness, rather than pushing to reach desired improvements in physical performance'

deemed the most important determinant of a successful strength and conditioning programme, with 42 of the 51 (82%) coaches suggesting this. Unfortunately, this was not an open response question. Athlete feedback could encompass a large range of possibilities. It would have been useful to know if this was the athlete enjoying the sessions because they were engaging, individualised, fun, easy or hard, or if they felt the sessions translated to an improved performance on the pitch. Likewise, feedback could be positive or negative, with both having an impact on the coach's session design or delivery. Without further questioning, we are unaware of any further detail. For example, the player may provide good positive feedback, but their performance scores may be suffering or stagnating. As coaches, we could be in danger of focusing on athlete happiness, rather than pushing to reach desired improvements in physical performance.

Injury rate was considered the second most important determinant of programming success.

As suggested in this study, performance enhancement and injury prevention are the dominant objectives of the monitoring process, with 84% and 82% of coaches suggesting this respectively. Focus on injury prevention is justified given the associated financial loss and negative impact on team success.^{4,17} As mentioned, it is ultimately the S&C coach's job to provide the coach with as many fit, robust and conditioned players for the longest period of the season. Therefore, ensuring that the players remain injury free is key to this success.

Interestingly, gym performance (n=38, 74.5%), eg, personal bests or weight lifted, and diagnostic testing feedback (n=32, 62.7%) were ranked higher than actual sport performance. This may ask the question, are S&C practitioners chasing 'gym numbers' or 'gym gains', over actual improvements in sporting performance? However, it could also suggest that sport performance is determined by a wide range of uncontrollable factors, and S&C input and physical performance is only part of the overall picture. Gym performance and

improvements in physical capabilities are only a part of the bigger picture. As S&C practitioners, we are tasked with improving physical capabilities; the assessment of actual performance should be performed by the sports coach.

Practical applications

The present study sought to conduct a comprehensive survey of strength and conditioning testing and monitoring practices in senior professional male football. The results of this survey should act as a resource for current and upcoming practitioners at all levels, to understand and assess their own and others testing and monitoring practices.

The original findings in this research are that practitioners will test and monitor their players to improve performance, prevent injury risk and manage training load. It appears that there is no universally adopted monitoring approach within professional football, although many clubs do adopt similar practices. Although there is a plethora of technology available to be used in professional sport, the majority of practitioners use relatively simple assessments throughout the season. The most frequently used assessments are body composition, training load via GPS data (both 82%), heart rate response (74%), player wellness (72%) and lower limb power via CMJ (59%). Assessment of body composition was the most frequently used test to assess the players during the pre-season period; with body composition and GPS tracking most common during the in-season. However, in-season testing of physical performance such as speed, change of direction and muscular strength were most commonly 'never' assessed. In addition, coaches value athlete feedback as the biggest determinant of a successful strength and conditioning programme ahead of any other indicator. However, more detail on what actually constitutes athlete feedback is required.

Physiological or performance assessments may be of little use when considered in isolation. It appears that practitioners use multiple assessments to provide a more

comprehensive picture of their athlete's response to training, as highlighted with clubs monitoring 9.7- 9.8 markers during the pre- season and in-season period.

Given that physical performance assessments are used to inform decision-making throughout the player development process, robust interpretation of test performance data is, therefore, paramount. Practitioners in this study do suggest that at least part of their procedures help form meaningful change in their decision-making process, but it is not clear if these practices have been shown to be reliable and valid in giving useful data. Irrespective of how an athlete's response to load is captured, it is crucial to critically appraise the reliability, validity and utility of the data being collected with respect of the context to which it is applied. Depending on resources and context, this may be achieved via 1) existing independent validation; 2) partnering with universities to perform new validation work; or 3) in-house or internal validation work. Any of these methods may help increase practitioner's confidence with a given technology to apply the findings to their club. Understanding which assessment

is applicable to your environment and understanding what the data actually means in terms of affecting your decision-making process are important factors when testing and monitoring football players.

Conclusion

This study provides new evidence that practitioners in professional football can use to review current practices and also provide new ideas for diversifying/modifying future practices. In addition, graduates or S&C coaches wanting to work in professional football may tailor their continued professional development to align with contemporary practices outlined.

In conjunction with previous research into the contemporary practices for S&C provision in football,⁶ information obtained from this research will allow coaches access to a serviceable source of the collective ideas of others that they can use to compare with their own provision, and potentially incorporate into their own practices. At this time, no such source of information exists for S&C testing methods in football.

AUTHORS' BIOGRAPHIES



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