Challenges and Solutions for Physical Testing in Sport: The ProPQ (Profiling Physical Qualities) Tool

Keywords: Physical Qualities, Fitness Testing, Data Management, Data Analysis, Strength and Conditioning, Data Visualisation

Abstract

The measurement, analysis, and reporting of physical qualities within sport is vital for practitioners to support athlete development. However, several challenges exist to support this process (e.g., establishing comparative data, managing large datasets) within sport. This article presents seven challenges associated with physical testing in sport and offers solutions to overcome them. These solutions are supported by a description of the ProPQ (Profiling Physical Qualities) Tool. The ProPQ tool uses advanced data analysis, visualisation and interactive elements, to enhance stakeholders use of data to optimise player development and coaching practices. The ProPQ is currently used across rugby league in England.

Introduction

Within sport, athletes must possess and develop a multitude of technical, tactical, physical and psycho-social attributes to be successful (11, 28). One important aspect for athlete performance and development is the focus upon physical development due to the relationship between physical qualities and sports performance (10), supporting recovery and training (24) and injury risk reduction (21). To date, a plethora of research is available presenting the physical qualities of a range of athletes (e.g., age groups, playing standard, positions) across multiple sports (e.g., basketball (1); gymnastics (49); rugby league (60); rugby union (42); tennis (17)). The assessment and evaluation of an athletes physical qualities are undertaken through implementing a physical testing battery, which is common practice within sport (35, 38). Physical testing can have multiple purposes including; 1) the quantification of the physical qualities of an individual (13, 27); 2) providing data for talent identification and development (56, 68); 3) the evaluation of an athlete's strengths and weaknesses (36, 55); 4) supporting goal setting (26); 5) monitoring and evaluating player development (5); and 6) evaluating the effectiveness of training interventions (40).

To achieve the purposes of physical testing and support athlete development, several steps must be undertaken. Firstly, sport practitioners must design and develop a valid, reliable and practically appropriate physical testing assessment battery based upon the physiological determinants of the sport and the contextual requirements of the environment (e.g., time, equipment, facilities; (36, 37)). Following the design of the testing battery, physical testing is implemented to collect the appropriate data. The data are then analysed (e.g., compared to comparative data, identify strengths and weaknesses) before being reported, fed back or visualized to a multidisciplinary staff team (e.g., sport scientist, strength and conditioning coach, sport coaches, academy manager, physiotherapist) and other relevant stakeholders (e.g., players, parents). Based on the analysis and feedback of these data, the multidisciplinary staff team can then make informed decisions on the athletes needs and subsequent training programme to enhance athlete performance and development (59) whilst other relevant stakeholders can use this information for motivation purposes. This process can then be repeated to inform an ongoing needs analysis whilst continually monitoring and evaluating the physical development of athletes.

To support and advance this physical testing process, a range of research, resources and practical recommendations are available, which has grown and improved over the last decade. These include the communication of common physical testing batteries including validity and reliability considerations (6, 13, 54) and the presentation of comparative data across multiple sports (42). The development of data analysis methods (e.g., z-scores (38), total score of athleticism (61, 62), evaluation according to age and maturity (58), higher dimensional analysis (57, 66)) have also been used to enhance practitioner data analysis and evaluation methods. Whilst this large and critical field of work is available and has enhanced physical testing practices, there are numerous challenges and potential problems for the design, delivery, analysis, reporting and evaluation of physical testing to effectively inform multidisciplinary staff teams and support the development of their athletes. Therefore, this article aims to present these challenges (based on the research literature and experience of the authors undertaking such work across 15 years) and then propose solutions to overcome these challenges within sport. These solutions are supported by a description of the ProPQ (Profiling Physical Qualities) Tool that has been designed by the authors to provide advanced data analysis, data visualisation and interactive elements for use by multiple practitioners within sporting organisations to support player evaluation and decision making when working with athletes in sport.

Challenge 1: Establishing Comparative Datasets

A plethora of information is available for physical testing within athletes. Such information has resulted in a large variability in the physical testing practices used in sport science and strength and conditioning. To exemplify this point, a recent systematic review in youth rugby union (42), found seventy-five tests have been used in the research literature across forty-two studies to quantify the physical qualities of body composition, muscular strength, muscular power, linear speed, change of direction ability, aerobic capacity and anaerobic endurance. As such, the decision-making practices of practitioners is difficult when designing physical testing batteries. Due to the large number of assessments available, alongside the lack of consensus on the most appropriate physical testing methods applied, this often leads to a large variability in the tests used within and between organisations within the same sport. This can also result (from our experiences) in different physical testing batteries being applied at certain times throughout a season (e.g., pre- vs mid-season), across different age categories or playing levels within the same organisation (e.g., professional club) and across different teams within the same sport. For example, to assess aerobic endurance, different practitioners may prefer and implement several tests (e.g., Yo-Yo intermittent recovery test, 30:15 intermittent fitness test and maximal aerobic speed tests) within and between organisations.

The large variability and inconsistent physical testing practices used within and between organisations can limit the establishment of comparative data for data analysis, evaluation of athletes and the decision making of practitioners. Limiting the establishment of comparative data then raises questions whether the objectives of physical testing (i.e., accurately quantify performance, evaluate athlete strengths and weaknesses, monitor player development) can be achieved. For example, if physical assessments differ between organisations in the same sport, practitioners are only able to evaluate the strengths and weaknesses of their athletes within their own training environment. Although this would help understand the strengths and weaknesses of athletes within an organisation it fails to consider their physical performance compared against other athletes and their strengths and weaknesses for the sport. Furthermore, implementing inconsistent physical testing across a season results in a failure to monitor and evaluate physical performance and development validly and reliably.

Solution 1: Standardised Physical Testing Batteries

To overcome the challenge of establishing comparative datasets, research has recommended the design and implementation of standardised physical testing batteries (42, 60). As a minimum, we recommend that standardised physical testing batteries are implemented within and across an organisation (i.e., within clubs) and ideally applied on a national basis across a sport. Such an approach has been successfully implemented within soccer (30) and rugby league (12, 46). The benefits of a standardised physical testing battery are that it allows a large and consistent comparative dataset to be established from multiple athletes, which in turn allows individual athletes to be compared to a large comparative dataset rather than using small, age- or club-based samples alone.

For the successful implementation of a standardised physical testing battery, the assessment should be scientifically designed so that it represents the physical qualities required for the sport whilst being valid and reliable. In addition to this, the assessment needs to be appropriate and practically designed so all organisations can be tested whilst not affecting their usual training programme. Therefore, depending upon the sport and number of athletes to be assessed, it may be required to test many athletes (e.g., up to 40 athletes) within a set time-period (e.g., 90-minutes) within one session. Ideally, when implementing a national standardised testing battery across multiple organisations, it is recommended that an external organisation (i.e., University) undertake the physical testing battery to ensure consistency in the way that the tests are conducted. Through the implementation of physical testing, other consistent practices should be applied including a standardised warm up, instructions and briefing, consistent order of testing, facilities, and environmental conditions. This would help ensure data are reliable and valid for cross organisation comparison (19). Where a standardised physical testing battery is implemented within an organisation across multiple age categories, we recommend that a staff member leads the physical testing to ensure standardisation across squads for the above benefits.

Challenge 2: Managing Data and Data Protection

Physical testing can produce large volumes of data, especially if standardised physical testing batteries are implemented. For example, it is common for many athletes to be assessed on multiple tests on several occasions across a season (e.g., 300 athletes, undertake 10 physical tests, three times a year = 9,000 datapoints). As such, large and complex volumes of data are often an outcome of physical testing that need managing to allow practitioners to appropriately analyse, evaluate and make decisions to support athlete development (18, 45). These management problems can include data errors, cooperation of multiple individuals across multiple sites, access to software, and data protection and privacy. In addition, due to the nature of such a project, flexibility within the management system is important to allow for continuous development and improvement at each step (50, 64).

Accounting for errors within data is a common first step within data analysis. These errors can present due to human error (e.g., incorrect transcription from paper to computer) or due to equipment malfunction (e.g., incorrect/missing readout from speed gates). Having a procedure in place to correct or remove these issues as appropriate allows for more confidence in the final analyses performed. In addition, given the nature of physical testing, it can be common for an individual to only complete a partial testing battery resulting in one or more missing datapoints. Ensuring these missing datapoints do not result in any recorded datapoints being removed is important to retain as much data as possible.

Due to the scale of a project such as a national physical testing battery, it is often not feasible for a single individual to meet all demands of the project. Therefore, it can require multiple people to perform the testing or different people for the different sections of the project (e.g. data collection vs data analysis). Having appropriate methods of file sharing in place can help the project flow smoothly.

As identified in Challenge and Solution 1, a standardised testing battery should allow for practitioners and athletes to assess and compare their data against a large comparative group (e.g., across all players within an organisation, across multiple clubs in a national protocol). While such an approach can give a better indication of an individual's data, data protection and privacy regulations prevent data from one organisation being readily accessible or identifiable to another without explicit permission. Similarly, the software or application being used to view the data needs to be one either currently used by all organisations or one that can be readily accessed by all organisations. Given that buy-in from all parties is important, using a tool that could be accessed with minimal barriers (e.g., licence fees, software download, user registration) is important.

Finally, due to the scale and differing demands of the various organisations involved, a flexible approach to data management is needed. One that will both meet the needs of the project from the national perspective but also be flexible to the demands of the different clubs involved. Such an approach should allow for alterations/improvements to be made at any step of the data management system.

Solution 2: Data Management Systems

To overcome these data challenges requires a system that allows for efficient data management and sharing across multiple users (within and/or between organisations). The effectiveness of this system is vital in the reporting of data to not only report accurate information but also maintain club engagement with quick feedback. By using data analysis software (i.e., *R: A language and environment for statistical computing*. Vienna, Austria R Foundation for Statistical Computing) in conjunction with other software/systems, data can be shared, cleaned, analysed and uploaded for organisations in a consistent and efficient manner.

To overcome data errors, it is important to identify and where feasible correct these errors. Should it not be possible to correct the error, then it may result in a missing data-point. This, along with the reason outlined above, may require a method to impute missing data. Imputation of the data prevents a whole observation being removed and therefore, retaining as much of the data as feasible (2, 33). As identified above, due to the potential scale of a standardised testing battery and to prevent the need for multiple versions of the same dataset, increasing the potential for errors to occur, a shared storage system is required. For example, Google Drive, a cloud storage system, allows users to update and share files seamlessly. In addition, there are R packages available which provide the ability to access and update these files within the coding window aiding the turnaround of data. Google drive also provides a common file path between users allowing the same R scripts to be used on different computers and institutional logins.

Google Data Studio is a data analytics platform that can effectively disseminate and share data with multiple practitioners from different organisations without requiring additional licences/fees. Through this platform, users are only required to have a Google account which has minimal sign up and no fees incurred. Similarly, Google Data Studio allows for each organisation to have their own bespoke dashboard that compares their own data to the national dataset without breaching data privacy. In order to do this an anonymised master database is used among all dashboards to constantly update the database with the most current knowledge, while new identifiable data for a unique team is updated following testing and added to their dashboard. With the solutions outlined, both the testing methods and analytics can be updated in a seamless and efficient manner allowing for flexible approach to meet the needs of all organisations involved in the project (See Figure 1).

Insert Figure 1 near here

Challenge 3: Data Analysis: Multicollinearity

As discussed in challenge 2, physical testing can create large volumes of data. In addition to the management of this data, a further issue is the highly correlated nature of individual variables within a dataset resulting in data multicollinearity problems (57). This means that some variables often collected within a physical testing battery may represent very similar information (e.g., 10, 20, 30 and 40 m sprint splits in a 40 m sprint test). This can therefore provide more data than are required or accessible for the practitioner to use effectively alongside creating challenges for the effective communication and use of the data by multiple practitioners and stakeholders within an organisation, especially when working across disciplines (e.g., sport coaches, strength and conditioning coaches).

Whilst recent publications have recommended data analysis methods to reduce multicollinearity or simplify the presentation and interpretation of data (e.g., z-scores (38), total score of athleticism (61, 62), higher dimensional analysis (57, 66)) some disadvantages exist with these methods. For example, most statistical data analysis methods are designed to be used by the sport scientist or strength and conditioning coach and may not apply or be used by other staff with less knowledge of data or statistical analysis (e.g., sport coaches and academy managers). Furthermore, limited data analysis methods have been presented that may be used by multiple practitioners to provide multidisciplinary support to an athlete. As such, more creative and useable strategies are required for use by multiple practitioners within a sporting programme to enhance the needs analysis process and help athlete analysis, evaluation, decision-making and programming.

Solution 3: Dimensionality Reduction Techniques

One solution to overcome large volumes and multicollinearity of data is the use of dimensionality reduction techniques, which include principal component analysis (PCA). PCA summarises and simplifies the information provided by a large and complex dataset (i.e., all data collected) by transforming the original variables within a data set into new variables known as principal components. The principal components are created by weighting the original physical testing measures (expressed as z-scores) to produce composite variables. These principal components are produced in a way that attempts to maximise most of the information within a reduced number of components, with each providing different information, allowing multiple variables to be presented and visualised more simply with minimal loss of information (65). Figure 2 presents an example of a PCA analysis of a physical testing dataset within rugby which created two principal components of predominantly 'strength and size' (x-axis; PC1) and predominantly 'speed and power' (y-axis; PC2) from a physical testing battery including height, body mass, body composition, isometric mid-thigh pull, countermovement jump, 10m sprint, maximum velocity and prone Yo-Yo (see (33) for more details). The positioning of a principal component score to the top right demonstrates superior physical performance whereas a score in the top left would represent superior 'power and speed' but below average 'size and strength'. Such PCA analysis has been used successfully within physical testing research (33, 57) and training load analysis (47, 66) with the favouring of presenting two principal components on a two-dimensional scatterplot for use by practitioners.

Insert Figure 2 near here

Within performance and development sport, this data analysis and feedback strategy may be useful for several purposes, including talent identification, quantification of athlete physical performance, strengths and weaknesses evaluation and goal setting. This strategy is particularly useful for multidisciplinary staff (e.g., coaches, scouts, academy managers) that require a 'snapshot' of an athlete's current performance and development in comparison to other athletes and reference data to help decision-making. For example, when planning an athletes overall training programme inclusive of physical, technical, tactical and psycho social development aspects, the use of these data can inform programming decisions. For example, an athlete scoring in the top right quadrant of a principal component matrix for physical qualities may be allowed more time to focus upon other aspects of development whilst an athlete appearing in the bottom left quadrant may require additional training focussed upon physical development.

Challenge 4: Monitoring Athlete Development over Time

Standardised physical testing and PCA are useful tools for the collection, analysis and evaluation of cross-sectional data. However, research has highlighted the importance of monitoring athlete development over time on multiple occasions using longitudinal methods (5, 53, 55). Longitudinal monitoring allows players to be tracked over time on short- (e.g., 6-week programme) to medium- (e.g., a season) or long-term (e.g., multiple years) to establish the development and progress (or regress) of an athlete. Whilst longitudinal monitoring has been recommended, challenges exist to its use including the implementation of consistent data collection methods (see challenge 1), and the time and resources (32) available to do this effectively. Alongside, the collection of longitudinal data, reporting, analysing, and evaluating longitudinal data may enhance the decision making of practitioners on several levels. However, reporting and presenting longitudinal performance change can be complex with numerous strategies available to establish physical changes including z-score tracking (55), effect sizes (35) and magnitude based inferences (23). However, optimising evaluation and feedback of longitudinal physical testing data can be a challenge and from our experiences is not something that is done well within practice.

Solution 4: Monitoring Data Longitudinally

To overcome the challenge of monitoring athlete development over time, the solution is to simply establish longitudinal data collection processes. This can be achieved through the development of a consistent, valid, reliable and practically applied standardised physical testing battery (as in solution 1) that is planned regularly into the annual plan (e.g., 3-4 times per year). The presentation of these data is then important. Using PCA can demonstrate athlete development across multiple timepoints to establish overall physical development and performance, which are associated with the benefits described in solution 3. Furthermore, tracking development using multiple tests (e.g., strength, speed, power) can help monitor the physical development of each physical quality. It is recommended to analyse this development using age and maturity regression equations (see solution 5). Such information may be useful to the multidisciplinary staff team and influence the identification and retention of athletes based upon physical development over time rather than snapshot physical performance alone (5, 53, 55). Furthermore, the evaluation of training programmes may allow practitioners to reflect upon their training programmes to establish the most appropriate future training intervention (59).

Challenge 5: The Influence of Age and Maturity

Whilst the above challenges and solutions highlight the importance of establishing a standardised physical testing battery and implementing testing regularly over time, these methods fail to account for the age and maturity status (in youths) of athletes. Traditionally, youth athlete's physical qualities are compared against a comparator mean and standard deviation within annual-age categories (e.g., Under 13s, Under 16s). For example, a 14-year-old athlete is compared with an age-matched Under 14 sample of scores. However, comparing youth athletes within annual-age categories can be confounded by other factors such as relative age (4) and maturity (9, 29). Relative age refers to an athlete's chronological age relative to the cut-off date applied to create chronological annual-age categories (e.g., September 1 in the United Kingdom). Therefore, athletes competing within the same age category are compared against the same comparative data although their chronological age may differ by 364 days (e.g., 1st September vs. 31st August in the United Kingdom). This annual-age grouping process has resulted in relative age effects (RAEs) whereby relatively older individuals are advantaged in participation and selection opportunities within sport due to their advanced age (4). Like RAEs, maturity biases exist within sport favouring earlier maturing individuals (15, 31). Therefore, due to large inter-athlete variability within chronological age groups , recent recommendations suggest comparing individuals according to age and maturity status (9, 44, 58). Such information would provide practitioners with greater insight into athlete evaluation. However, although recommendations have been made, the implementation of such practices may be limited.

Solution 5: Age and Maturity Regression Equations

To overcome this problem, it is recommended that physical testing data are presented as a regression equation rather than using standardised age group mean and standard deviations. Such a strategy allows an athlete's performance (both one off and longitudinal) to be compared at a specific chronological age point (e.g., 15.01 vs 15.99 years rather than Under 16s). To achieve this, it is recommended to establish local polynomial regression fitting (loess) between the physical quality and chronological age (and maturity status where possible and depending on the age of your athletes) to enhance data interpretation (58). Loess performs localised regressions on the data while also reducing the weighting given to extreme values (i.e., outliers) which combined, allow for an accurate estimate of the standard for a measure at a given age. Allowing an athlete's physical qualities to be tracked over time relative to the average for age related improvements is a key aspect of this analysis. Figure 3 shows the use of loess regression equations for an athlete that can track their performance over time. Such analysis provides greater detail and insight into a player's development over time in relation to the comparative data, which can be used by strength and conditioning coaches for specific programme design.

Insert Figure 3 near here

Challenge 6: Visualisation and Interpretation of Data

As identified in the above challenges, a goal of physical testing is to assess and understand where an athlete currently is in their development to inform training interventions. However, there are multiple considerations that need to be taken into consideration here to inform this decision making including age/maturation; playing position; comparison against national dataset and against own club data. However, there is a need to do so in a simplified, easy to use and easy to update manner. In addition, the practitioner's ability to have flexibility within a system to answer any specific questions they may have of the data is required. Therefore, the opportunity to provide greater insight, detail and factors to inform staff evaluations and decisions would be deemed important. In most reporting and feedback systems this option is not available.

Solution 6: Interactive Data Visualisation

Creating buy-in from staff and organisations is a key factor to successfully implement a physical testing programme. Therefore, providing opportunities to visualise data for effective and efficient communication of data and providing flexibility to answer questions from all users is important (52). As such, the development and implementation of interactive data visualisation methods are important. Interactive data visualisation refers to the use of modern data analysis software that enables users to directly manipulate and explore data (50). While data visualisation uses visual aids to help users understand data, interactive data visualisation incorporates tools that allow users to modify the data they are viewing, enabling them to see more detail and capture the full value of the data whilst potentially answering the questions they are asking. Figure 4 shows how an interactive data visualisation can be applied to PCA analysis to make comparisons by (A) age category, (B) playing position and (C) date of testing, and (D) all three. This allows users to manipulate the tool to visualise subsets of the data, allowing comparisons between positional groups, age groups and/or between certain players.

Insert Figure 4 near here

When developing an interactive data visualisation tool there are various considerations to ensure the simple and informative relay of data. To ensure data are communicated effectively, it is recommended to prioritise the presentation of certain variables (e.g., only five physical measures are visualised; see Figure 3 and 4) and ensure visuals are clearly presented. The use of standardised colours (e.g., blue represents all players and red represents individual players) allows easy interpretation. The data should be "tidied" (e.g., appropriate decimal placing used) to remove unnecessary noise, along with ensuring text is readable and formatted for easy interpretation. The use of a polynomial regression line in place of banding or color-coding athletes allows for quick interpretation of data.

Challenge 7: Objective Data - 'It's Important, but not Everything'

A physical testing battery has numerous positive implications for both stakeholders and athletes which have been highlighted above. However, objective physical testing alone may only provide a one-dimensional view of an athletes physical ability (48), and not fully representative of overall sporting performance (7). Consequently, the implementation of objective physical testing batteries are void of subjective input from the coaches' eye (8). For example, recent research (34) identified that rugby league practitioners (i.e., coach, S&C coach) typically perceived physical testing and the use of subsequent data as "important, but it's not everything", and indicated multiple other factors must be considered within player evaluations. According to the practitioners, routine physical testing can provide useful context regarding a player's current physical state, track development, positively impact the training environment, and inform training programmes. However, in contrast, physical tests were deemed to not effectively assess the athlete's physical characteristics for match-play or provide an indication of their rugby ability. Moreover, performance during physical tests was highlighted as being highly variable in nature and governed by a myriad of factors (e.g., maturation, the individual, injury), which have been addressed in solutions 4, 5 and 6.

Correspondingly, practitioners such as the sport coach, scout, management, S&C coach and/or sport scientist must consider information from multiple sources when making important decisions (3, 22) such as evaluating players, establishing athletic development plans and the inevitable and necessary process of talent selection (43, 51). Although multidimensional approaches to talent development have been advocated (63, 67), such decisions are largely reliant on coaches' subjective assessment of their players (25). Moreover, rugby league practitioners typically assess players physical performance without using objective measures (34), limiting their prognostic ability. Therefore, given the importance of implementing physical testing to generate informative data, the combination of both objective data with subjective practitioner opinion will contribute to more holistic player evaluations.

Solution 7: Using Subjective and Objective Methods to Profile Players

The integration of subjective practitioner opinion and objective physical testing data can promote multidimensional player assessments leading to enhanced analysis, evaluation and practitioner decision making. For example, a combination of coach assessment and performance tests were the most accurate predictor of career attainment in youth soccer (48). The inclusion of subjective assessments addresses a broader spectrum of performance indicators in comparison to objective physical tests alone and helps triangulate or contradict objective data based on expert opinion. Furthermore, such assessments may include detail on the individual (e.g., injured for previous 6 months), complex skills (e.g., passing, tackling), and/or psychological attributes (e.g., attitude) that are almost impossible to collect within a physical testing battery. Such information may be key to inform player development and performance, however, the accuracy of the coaches' eye has been questioned when evaluating physical (14), technical performance (7), and maturity status (20). As such, practitioners should utilise objective data over subjective opinion to promote accuracy when making decisions regarding a player's physical performance. In addition, objective data provides a rigorous evidence base to be used to either support or defend opinion when evaluating player performance (39). Lastly, as some individual's respective strengths may not be evident throughout physical testing, quantifying, and storing subjective assessments is encouraged, and should be included within player assessments to support optimal practice (e.g., longitudinal assessment). In doing so, this process may encourage stakeholders to appraise players in more detail while supporting their multivariate development. Therefore, taking holistic, multidisciplinary player evaluations including objective data and subjective practitioner opinion may be an appropriate monitoring and evaluation tool to consider for the future.

The ProPQ (Profiling Physical Qualities) Tool

Based on the above challenges and solutions, the ProPQ tool was designed, developed and implemented across rugby league in England for both male and female athletes. The above solutions sections offer ways in which the tool has been designed (see Figures 2,3 and 4) and present this in a way that other organisations could use such methods to overcome their own challenges associated with physical testing to support clubs in informing their athlete evaluations and support practitioner decision making. To see an example prototype of the ProPQ tool please see the link - https://datastudio.google.com/reporting/db44f3b7-2c71-4542-8ed0-fc07d2d8a046). The ProPQ tool has allowed all professional rugby league academy players aged between 15-19 years in England to be assessed for their physical qualities. This has created a large comparative database of over 1,500 players. The ProPQ tool uses PCA analysis to provide an overall assessment of where an individual player is compared to the national standardised dataset (Figure 2), allows stakeholders to be interactive with the tool to change the comparator dataset according to age group, playing position and date of test (Figure 4). This process provides an opportunity for players to be discussed by a multidisciplinary team to establish their training and development programme moving forward. In addition, individual physical tests are presented according to the loess regression analysis that also allows athletes to be tracked and monitored longitudinal (Figure 3) providing greater insights into their physical development, it is envisaged that strength and conditioning coaches would use this level of insight to inform physical development programming. In summary, the ProPQ allows 1) athletes within a club to be compared between (anonymised) athletes within other clubs and 2) national governing bodies the opportunity to monitor players and provides more objective data for international and representative selection. This can be a useful tool for practitioners within clubs to motivate their 'best athletes to be better' and help inform practitioners decision making.

Whilst the implementation of this tool can address several challenges associated with physical testing, especially analysis, visualisation and interpretation of physical data, at present the ProPQ only focuses upon physical qualities. However, as athlete development is multidisciplinary and the need for objective and subjective data is required, other sports and organisations may consider how they continue to develop a multidisciplinary athlete profiling tool that may further support practitioners in working together to inform talent identification and athlete needs analysis, whilst continually monitoring and evaluating athlete development and training programme effectiveness.

Summary

The measurement, analysis, and reporting of physical qualities within sport is vital for practitioners to support athlete development. In this article we have considered seven challenges to implementing physical quality athlete profiling including 1) Establishing comparative datasets, 2) managing data and data protection, 3) data analysis and multicollinearity, 4) monitoring development over time, 5) influence of age and maturity, 6) visualisation and interpretation of data, and 7) objective data: it's important but not everything. These challenges highlight the complexities and intricacies of physical qualities and how it needs to be analysed, visualised, and evaluated to inform decision making of a range of practitioners to inform athlete development. To overcome these challenges, we propose a range of solutions including the design, management, analysis, evaluation, reporting, visualisation of data and need for multiple perspectives. Such solutions have informed the ProPQ tool, which has been successfully implemented and used across rugby league in England. However, several challenges exist to support this process (e.g., establishing comparative data, managing large datasets) within sport. This article presents seven challenges associated with physical testing in sport and offers solutions to overcome them. These solutions are supported by a description of the ProPQ (Profiling Physical Qualities) Tool. The ProPQ tool uses advanced data analysis, visualisation and interactive elements, to enhance stakeholders use of data to optimise player development and coaching practices. The ProPQ is currently used across rugby league in England. We recommend other sporting organisations including professional clubs and national governing bodies consider such strategies to support their athlete and practitioner development programmes.

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Figure Legends

Figure 1: Data Management Workflow

Figure 2: Principal Component Analysis Scatterplot
Figure 2 *Note*: The blue dots represent all datapoints, the red dot represents an individual player. This datapoint shows this player has above average power and speed but below average size and strength.

Figure 3. Loess Regression equations for tracking athlete performance over time
Figure 3 *Note*: The blue dots represent all datapoints, the orange dots represent an individual player assessed across 8 time points over an 18-month period. This data shows the variability in performance over time for Yo-Yo performance, Countermovement jump, isometric mid-thigh pull, 10m sprint and maximum velocity

Figure 4: Example of an Interactive Data Visualisation Method
Figure 4 *Note*: Options in box show how data can be visualised according to age, position, date of testing and specific players. Blue dots represent the players assessed within Under 16 forwards within rugby league.