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Evaluating a Current Athlete Assessment Program

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Evaluating a Current Athlete Assessment Program

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ABSTRACT

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The primary purpose of this dissertation is to evaluate the effectiveness of a questionnaire designed to assess coaches' perceptions of an athlete monitoring program. There are four reasons for this examination of perceptions: 1) it may serve as a check for understanding of how the coach takes in the information presented to them, 2) identify any gaps in the knowledge of the coach which the sport scientist may help to fill, 3) can serve to open a dialog with the coach for ways in which the information may be better tailored to help them improve their decision-making, and 4) the feedback provided can shed insight towards the areas a sport scientist can make more robust (e.g., delivery of information or structure of a training program). Coaches participating in the athlete monitoring program at East Tennessee State University's (ETSU) Sport Performance Enhancement Group (SPEG) were invited to participate. There were no statistically significant differences between the pre- vs post- questionnaire responses.

The secondary purpose of this dissertation is to examine the outcomes from the questionnaire and develop an understanding of the present responses. Considering the range of responses submitted by coaches, this serves as an indicator for the sport scientist/Strength & Conditioning Coach to prompt a dialog with the coach of the team they work with to better understand what else they may contribute towards enhancing the coach's experience with such services.

The tertiary goal of dissertation section is to provide practitioners who are interested in developing a sport scientist program for assessment of athletes with resources to better approach the logistics for developing their own system. Considerations included applying evidence-based practice, implementing precursor methods leading up to data collection (e.g., pre-testing certifications, lab set up, data collection, and testing protocols), approaching data collection (e.g., factors related to assessments, athletes, and additional considerations cover aspects of assessment validity and reliability), and potential assessment methods to consider (e.g., hydration, body composition, vertical jump height (VJH), and maximal strength).

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TABLE OF CONTENTS

LIST OF TABLES

Chapter 1. Introduction

Assessing athletes with monitoring methods is regularly becoming integrated into sports at most levels. The intention of incorporating these practices along with athlete training experiences is to provide practitioners with data that can inform the decision-making process leading to improved athlete performance. Specific monitoring focal points include determining program efficacy and fatigue management (Stone et al., 2007; Stone et al., 2022). Program efficacy is necessary since it is a means by which the implemented training modalities can be evaluated to determine their effectiveness with alterations in physical, psychological, and performance characteristics (Stone et al., 2007; Stone et al., 2022). Similarly, fatigue management is applied to the manipulation of training program variables and the training process in an effort to increase the likelihood of influencing the determining the level of fatigue present in training, so it does not impede adaptation (Stone et al., 2007; Stone et al., 2022).

Athlete monitoring serves as an approach to both long- and short-term evaluation of the athlete and their performance outcomes. Program efficacy will typically occur with the goal of identifying changes that take place over greater spans of time (weeks to months), with measurements of specific selected characteristics of interest obtained using an instrument(s) (McGuigan, 2016a; Thibault et al., 2012). Fatigue management is typically conducted on a more regular basis (daily or weekly) with the goal of providing information about the athlete leading into a training session (e.g., physiological or psychological strain, training volume or load, and recovery) (Fukuda., 2019). Appropriate standards should be considered that encompass important metrics that relate to sports and are quantifiable (e.g., strength, power, speed, etc.) (Reed et al., 2014; Stone et al., 2022).

As sport has developed, so have the training methods and performance outcomes. Developing alongside these evolving approaches to training and enhanced ability to perform is the need for evaluating the monitoring outcomes. To effectively understand where current monitoring practices are today, it is important to first examine their developmental foundation. Some of the modern monitoring methods can be traced back to a little over 100 years ago, with these practices of assessing athletes developing substantially since then. Substantial evolution in the methods has occurred since then. Practices such as assessing anthropomorphic characteristics (Bertillon., 1893), jump testing (Sargent., 1921), and the isometric pull are examples of some of the original methods still present in much of the field of sport science. Other more recent methods, such as the modifications of the isometric mid-thigh pull (IMTP), have seen significant development in just the past few decades (Haff et al.,1997: Stone et al., 2019). Then there is also the use of subjective tools such as the Borg RPE scale from about half a century ago, which was used to determine the level of perceived exertion as a means of evaluating physiological stress indicators (Borg., 1970).

As monitoring practices have evolved over time, this has driven change in the process of collecting data. As a result of this evolution, wearable technology, athlete-friendly (or more comfortable methods), minimally invasive, undetectable (ideally), and part of the environment while achieving some degree of imperceptibility (French & Ronda., 2021). A range of assessments used for athlete monitoring frequently includes hydration status, anthropometrics, strength capabilities, endurance capacity, sport-specific execution of skills, quantifying volume (i.e., mileage, training load, etc.), and readiness questionnaires. With an increased number of monitoring options available, selecting the approaches that help to best understand the status changes athletes undergo from training. This requires determining the variables from data collection that will be examined, often with the assistance of a knowledgeable coach or sport scientist. When developing an athlete monitoring system, considering a framework developed by Thornton and colleagues (2019) is a worthwhile place to begin. This approach consists of four steps: 1) considerations for athlete monitoring (i.e. how data will get collected, what are the potential limitations are of certain variables, and how these data can be effectively reported back to coaches and athletes); 2) methods of analyzing data (i.e. storing of data, who has access to it, and how the data is refined into something meaningful); 3) meaningful changes in data (i.e. applying methods can identify meaningful changes data: standard deviation, typical error, effect sizes, smallest worthwhile change, coefficient of variation, and magnitude-based inferences); 4) effective methods to present and communicate important information (i.e. determining the appropriate variables to share, delivering the information with the right visuals and prompts, while also using language your audience can comprehend) (Thornton et al., 2019).

The role of a sport scientist, similar to monitoring practices, has evolved as well, albeit more recently. The sport scientist "applies expert-level knowledge and skills to the training process, obtains and analyzes information, and evaluates processes, to solve problems and improve performance outcomes for the organization/sport and the athletes working within it, while enhancing the coach-athlete relationship" (Gleason et al., 2022a). This professional is also expected to "relate the findings of investigations, provide relevant and timely information to stakeholders, and share ideas in public forums and through research projects" (depending on job requirements) (Gleason et al., 2022a). A sport scientist is able to access knowledge on a broad range of topics with an emphasis towards an area of specialty. Areas sport scientists may specialize in include the fields of sport psychology, sport biomechanics, sport physiology, "skill acquisition, enterprise, and decision making", or kinanthropometry (Gleason et al., 2022b). Skills that a sport scientist must learn to be effective within their discipline range from communication, process development, implementing organizational structure and reporting lines, and sound leadership and followership skills (Gleason et a., 2022c). An effective sport scientist is also able to provide constructive insights, positively affect the athlete training process, and maintain a good working relationship with organizational partners (Gleason et a., 2022c). Additionally, recent responsibilities for this role have shifted towards ensuring that the technology used by a team is useful for providing solutions (Dellaserra et al., 2014; Torres-Ronda & Schelling., 2017). A sport scientist needs to have a broader understanding of the previously mentioned areas (i.e., sport biomechanics, sport physiology, etc.) to be most effective in aiding performance and reducing injuries. Overall, the goal of a sport scientist is to function as a member of the support staff who is involved in the training process, aids as a problem solver and educator, and can speak all languages involved with sports medicine, coaches, athletes, physical therapists, and medical doctor (Hornsby et al., 2021).

However, at some point, there needs to be an opportunity to evaluate current monitoring procedures that are in place. One approach that can be useful to obtain meaningful information about the perception of currently implemented procedures is a questionnaire. Questionnaires allow sport scientists a mean to assess the subjective training efficacy and the relative recovery status of the athletes (Reed et al., 2014). Specifically, using a questionnaire to evaluate the effectiveness of current monitoring practices can be a standardized method of discerning opinions, beliefs, attitudes, and behavior towards what is implemented (Boynton & Greenhalgh, 2004).

In 2006, the East Tennessee State University (ETSU) Exercise and sport science Program, in cooperation with the Athletic Department, developed a Sports Performance

Enhancement Group (SPEG) program with the main goal of providing athlete monitoring and coach feedback to enhance the training practices, asl well as to provide students with opportunities to work in an athlete monitoring program in a supervised environment. The SPEG program became part of the Center for Excellence in sport science and Coach Education (CESSCE), and functions alongside the Sport Science graduate programs. This program delivers athlete monitoring for various sports at the high school, collegiate, professional, and elite level. It provides graduate education aimed at developing better coaches and sport scientists. An overarching goal of this program is to positively influence athletic performance and an athlete's career longevity and improve coach performance by alleviating some of the figurative load from the coach. An important aspect of any program is self-efficacy assessment and periodic evaluation of the program's performance.

Therefore, the primary purpose of this investigation is to examine the outcomes from the questionnaire and develop an understanding of the present responses. The secondary purpose of this investigation is to examine the reliability and factor structure of a questionnaire designed to assess coaches' perceptions of an athlete monitoring program. While individuals from different areas of specialization (e.g., strength and conditioning or sport science) work together to provide guidance, they work to help the sport coaches to make the best decisions based on available information. Because they have the most direct influence on the outcomes, it is important to evaluate their perception of the monitoring program. There are four reasons for this examination of perceptions: 1) it may serve as a check for understanding how the coach takes in the information presented to them, 2) identify any gaps in the knowledge of the coach which the sport scientist may help to fill, 3) can serve to open a dialog with the coach for ways in which the information may be better tailored to help them improve their decision-making, and 4) the feedback provided can shed insight towards the areas a sport scientist can make more robust (e.g., delivery of information or structure of a training program).

Chapter 2. Review of Literature

The purpose of this literature review was to provide a brief history of assessing athletic performance. Background information relates to the practical considerations when developing and implementing a monitoring protocol, while also expanding upon questionnaires as tools to evaluate such protocols. This first section will provide information related to the history of assessing athletic performance and major concepts related to evaluating the effectiveness of obtaining data in the field. The following section will focus on evaluating implemented sport science and strength and conditioning methods in the organization. The final section will provide context on questionnaires as a tool to apply towards gaining a better understanding of others' opinions, beliefs, attitudes, and behavior.

History of Athletic Performance Assessments

Assessments are a specialized tool that can help to provide a clearer view of the current state of an athlete or a team. Assessments act as an indicator for the decisions related to the management of the athlete, talent development, and standardized training program (Fukuda., 2019). Prior to many of the modern methods of assessment that exist today, conceptually similar approaches to monitoring existed over 100 years ago. Practices such as assessing anthropomorphic characteristics (Bertillon., 1893), jump testing (Sargent., 1921), and the isometric pull are examples of some of the original methods still present in the field of sport science. Anthropometric assessments now include multiple compartment models available through a range of testing, allowing for a more encompassing snapshot of the athlete's current composition. While jump testing has advanced with the use of modern technology (e.g., force plates, accelerometers, linear position transducers, high-speed video, etc.) and can now provide many more metrics in addition to the vertical height the athlete achieved (e.g., impulse, peak power, velocity, and force output). Other more recent methods, such as the modified isometric mid-thigh pull (IMTP), originated in just the past few decades (Haff et al.,1997; Stone et al., 2019). Despite being a more current assessment, the research conducted in recent years with the IMTP test has allowed the positioning of the athlete to become better standardized and for the set up to become increasingly cost-effective (Comfort et al., 2019; Eserhaut et al., 2023). There is also the use of subjective tools such as the Borg RPE scale from about half a century ago. This tool helps determine the level of perceived exertion as a means of evaluating physiological stress indicators (Borg., 1970). Since then, there has been a range of subjective assessments developed to determine the wellness status of the athlete as well as the rating perceived of exertion during training/games (Haddad et al., 2017; Impellizzeri et al., 2004; Thorpe et al., 2015; Thorpe et al., 2016). Major commonalities that exist across many methods of assessment as they developed over time include:

- Improved capability of obtaining additional metrics
- The cost of performing the test (set up and equipment used per athlete) is becoming more affordable
- Assessment methods are becoming more widely used and accessible than ever before.

These developments allow the use of modern assessment practices on a regular basis with practitioners. Being able to effectively use the data obtained from these assessment methods is more common now than ever before.

Effectively Evaluating Sport Science and S&C

Baseline Measurement & Approaching Assessment

Monitoring athletes requires a baseline of performance to be determined to provide context on the measurements obtained during data collection. Baseline measurements establish starting points against which achievable goals can be set, and testing at regular intervals can help track an athlete's progress towards reaching those goals (McGuigan, 2016a). Considerations when selecting tests should include sport specificity (e.g., metabolic energy systems, biomechanical movement patterns), athlete experience, training status, age, and environmental factors (McGuigan, 2016a). Further, there should be a thorough understanding of the basic energy systems (phosphagen, glycolytic, and oxidative) and their interrelationships in order to apply the principle of specificity when choosing or designing valid tests to measure athletic ability for specific sports (Buchheit & Laursen., 2013; Fox et al., 1993; Joyce & Lewindon., 2014; Turner & Stewart., 2013).

A wide range of assessments are available to evaluate the current status of the athletes. Often, the laboratory setting allows more specialized equipment, producing more accurate results (Billat et al., 1999; Noakes., 1988). However, field tests serve as a tool for coaches to assess necessary basic physical abilities and the technique and training practice that could produce a competitive player (McGuigan, 2016a). Field testing assesses ability/skill away from the laboratory and does not require extensive training or expensive equipment (Chu & Vermeil., 1983). Laboratory testing is often where the gold standards of general assessments are frequently used, while field tests is a more ecologically valid assessment (Fukuda., 2019).

Steps suggested by McGuigan (2016b) that contribute towards sound testing outcomes:

> 1. Select tests that will measure the specific parameters most closely related to the physical characteristics of the sport or sports in question
>
> 2. Choose valid and reliable tests to measure these parameters and arrange the testing battery in an appropriate order with sufficient rest between tests to promote test reliability
>
> 3. Administer the test battery with as many athletes as possible
>
> 4. Determine the smallest worthwhile change for the tests and compare to normative data where appropriate (when using standardized procedures, the recommendation to develop personalized norms)

5. Conduct repeat testing (e.g., pre-, during, and post-training program) and present the results in some visual way

6. Use the results of the testing in some meaningful way (identify the strengths and weaknesses of the athletes and to design future training programs based on the obtained information)

Overall, appropriate monitoring helps the coaches and support staff better understand the impact training decisions can have on athlete development, preparedness, and readiness. By identifying monitored markers of performance, coaches and support staff can effectively guide and manage an athlete's performance capabilities (Stone et al., 2007; Stone et al., 2022).

Additionally, when adequate structure is present, a monitoring system aids in enhancing the understanding of proper choices that underpin long-term athlete development. The use of these identified variables or preferred training decisions can enhance the progression of athletes through a career-span (Stone et al., 2007; Stone et al., 2022). Furthermore, a monitoring system may help elucidate indicators of future training states and resultant training modifications (Stone et al., 2007). When designing a comprehensive monitoring program, included tests should (Stone et al., 2007):

- Reflect the nature of the sport (specific to performance aspects)
- Reflect the degree of fatigue management as much as possible
- Identify potential imbalances
- Administration of the test and timeliness of the data return should be concise
- Presented information should be understandable by the coach (depending on the coach's background, this will dictate how to deliver the data)
- The process continues to improve so it is refined into a more robust operation

Logistical Considerations

There is a range of considerations that are worth investing thought towards when developing an approach to athlete monitoring. Major items include ensuring (1) prioritizing the health and safety of athletes; (2) testers should be carefully selected and trained; (3) selected tests and practices of data collection are considered valid; (4) tests should be well organized and administered efficiently; and (5) athletes should be properly prepared and instructed (McGuigan, 2016a).

First, covering medical considerations is an essential component of monitoring that takes place before collecting data. The medical approval from sports medicine staff or a physician is a necessary facet required prior to participation to ensure the maintenance of the athlete's wellbeing during the monitoring process. Well-being for an athlete is a lot more than health – for athletes' well-being includes performing at optimum levels. Athletes should receive medical clearance before physical training and competition. Identification should of testing conditions and demands that can threaten the health of athletes should occur before training initiation. All those involved in testing should be observant of signs and symptoms of health problems that warrant exclusion from testing (Bergeron et al., 2012). Medical referral may be warranted for an athlete who persistently has any of the following symptoms: chest pressure, pain, or discomfort; listlessness; light-headedness; dizziness; confusion; headache; deeply reddened or cold and clammy skin; irregular pulse; bone or joint pain; blurred vision; nausea; or shortness of breath, rapid pulse, or weakness either not commensurate with the level of exertion or unresponsive to rest (McGuigan, 2016a).

Next, testers who will aid in the collection of data help to ensure the maintenance of an athlete's wellbeing (again wellbeing is more than typical health aspects) during the procedures. This requires careful selection of staff and training for possible situations to take place. Common consideration for conducting tests include setting up equipment, effectively delivering the protocol to the participants, adhering to standardized cues and practices, providing meaningful feedback to athletes as needed, and being able to aid in the resolution of any non-productive issues that may arise (Fukuda., 2019; McGuigan, 2016).

Regarding test sequencing, the administration of one test should not effect or potentiate the performance of a subsequent test. This is in an effort to enable optimal performance in each test and allows for valid comparisons with previous testing results (McGuigan, 2016a). A suggested approach it to administer tests in this order (McGuigan, 2016a):

1. Non-fatiguing tests (e.g., height, weight, flexibility, skinfold and girth measurements, vertical jump)

2. Agility tests (e.g., T-test, pro agility test)

3. Maximum power and strength tests (e.g., 1RM power clean, 1RM squat, isometric mid-thigh pull)

4. Sprint tests (e.g., 40 m sprint with split times at 10 m and 20 m)

5. Local muscular endurance tests (e.g., push-up test)

6. Fatiguing anaerobic capacity tests (e.g., 300-yard [275 m] shuttle)

7. Aerobic capacity tests (e.g., 1.5-mile [2.4 km] run or Yo-Yo intermittent recovery test)

Additionally, it is best practice to administer fatiguing anaerobic capacity tests and aerobic tests on a different day than the other tests when possible. This consideration is to reduce the impact fatigue may have on performance. If testing on another day is not feasible, then the most fatiguing tests should be performed last, after an extended rest period (McGuigan, 2016a). Characteristics of the subjects getting tested, such as age and sex can affect the validity and reliability of a test. Additionally, environmental conditions should not differ from test to test (e.g., the surface should always be the same [not turf to track surface or wet for one test and dry for another], altitude, the type of equipment used should be consistent, and, in instances of maximum strength tests, supports set at the same height for a given athlete) (Baumgartner & Jackson., 1988; McGuigan, 2016b). Especially with instances of high ambient temperature in addition to high humidity, which can impair endurance exercise performance, pose health risks, and lower the validity of an aerobic endurance exercise test (McGuigan, 2016a). To control for environmental factors testing should occur indoors when possible (Baumgartner & Jackson., 1998). However, if an indoor facility is not feasible, it is good practice to measure and document the environmental conditions and consider these factors when interpreting the results (Hayes et al., 2014; Parkin et al., 1999; Sparks et al., 2005).

Finally, standardization, athletes being tested for program efficacy should never test immediately after fatiguing sport activities or workouts (McGuigan, 2016b). They should arrive for testing normally hydrated and with standard nutrition before commencing the testing (McGuigan, 2016b). It is best to perform tests and retests at approximately the same time of day (Reilly & Waterhouse., 2009). Implementing a standardized warm-up and testing protocol is necessary for obtaining reliable data. An appropriately organized warm-up consists of a general warm-up followed by a specific warm-up, with both including movements similar to those involved in the test (Baumgartner & Jackson., 1998).

Questionnaires

Questionnaires are a viable tool for discerning information about a given topic. Questionnaires as a tool are a quantifiable approach to discerning others' opinions, beliefs, attitudes, and behavior (Boynton & Greenhalgh, 2004). While considerable thought needs to go into structuring a questionnaire, it is a very customizable tool that, once validated, can provide significant insight into the perceptions and behaviors of a given population. Customizability is largely due to the inclusion of certain types of questions and how these questions pertain to the desired information. The types of questions can range from open-ended, closed, open response option, and contingency questions (Etikan & Bala., 2017). Open-ended questionnaires allow the respondent to provide free responses to the questions. This question type allows the respondent to include as much detail in the answers as they choose. However, when using this set up, advance planning should take place to analyze the data. (Etikan & Bala., 2017). The closed questionnaire can range as nominal or ordinal data, ranging from categorical responses (i.e., "yes or no" or "good or bad") to a Likert Scale (e.g., unable to respond, neutral, agree, disagree, etc.). It is of importance to note that the use of terms such as "regular" (implying a pattern) or "frequently" (simply denoting regularity, but not a pattern) are discouraged, unless additional information is provided to provide clarity (e.g., "regular (1-3 time a week)" or "frequently (every day)") (Boynton & Greenhalgh, 2004). The closed design study helps in producing very urgent and summary data but lacks details of low response and sometimes results in frustration (Etikan & Bala., 2017). The open response option questions provide specific response options. While this may seem similar to the closed responses, specific answers are provided that the respondent may select from. An example of this is "What do you like most about this product?" the options for the answers are; quality, price, performance, weight, and other. This limits responses so they will not be able to provide different responses to those suggested while also suggesting answers that he may not considered before (Etikan & Bala., 2017). Finally, contingency questionnaire exist as a close ended question generally used for a subgroup of respondent. Here, the researcher asks filter questions that focus on a subgroup of respondents, while other respondents will answer some other set of questions that they skipped to the advanced section of the questionnaire (Etikan & Bala., 2017).

Additional considerations pertaining to questionnaires include making them easy to read/follow, kept short (about 12 words or less), and to the point (Howitt & Cramer., 2003). Questionnaires should begin with easy questions and progress towards more difficult questions towards the end to ensure the collection of higher quality responses from participants rather than discouraging them with challenging questions early on (Etikan & Bala., 2017). This approach also helps to combat the careless or “jump answers” respondents may provide if they are fatigued or grow impatient. It is best practice to introduce important questions in the early part of the questionnaire while less sensitive questions should appear later (Etikan & Bala., 2017).

A newly developed individualized questionnaire may identify unique aspects/characteristics, but using a previously validated and published questionnaire is also an approach to consider. The benefits of using a validated and published questionnaire include time saved with developing and validating the tool as well as resources (e.g., money). Additionally, you will then be able to compare your findings with those from other publications (Boynton & Greenhalgh, 2004; Etikan & Bala., 2017).

In the context of sport, questionnaires could allow sport scientists and coaches a means to evaluate a training protocol as well as the recovery status of an athlete. The use of questionnaires in sport provides a method of evaluating the enhancement of practices that relate to the evaluation of monitoring procedures as well as the return of data. One specific questionnaire that is highly applicable to evaluating the beliefs individuals hold is an instrument developed by Pace titled the College Student Experiences Questionnaire (CSE-Q) (Pace, 1984). This tool has the goal of evaluating the experiences of undergraduate students and what they believe led to the attainment of their goals, specifically learning outcomes (Pace, 1984). The events examined by the CSE-Q were considered as opportunities provided by the university or available resources from attending a university that led to the enhanced outcomes of student learning (e.g., classroom, library use, clubs and organizations, interactions with faculty members, etc.) (Pace, 1984). Relating this tool to the evaluation of monitoring procedures used in sport, provide a method for program assessment and effectiveness (Reed et al., 2014).

Questionnaires: Perception of Performance

Data obtained from questionnaires hold practical relevance by being designed to include criteria that directly refer to what is being asked. One such questionnaire is the Elite Athlete Self-Description Questionnaire (EASDQ), developed by Marsh and colleagues (1997) to measure six components (skill, body, aerobic fitness, anaerobic fitness, mental competence, and overall performance) of the elite athlete self-concept that make up performance. The six components can be defined as follows: skills refer to perceptions of skill in a specific sport, body is how well the body suits a specific sport, aerobic fitness refers to the ability to perform long duration endurance events, anaerobic fitness is the ability to perform short yet highly intense bursts of activity, mental refers to an athlete's ability to self-motivate, and performance is the degree to which an individual excels in a specific event (Marsh et al., 1997). Each of these aspects require a perception of overall athletic performance, which is why Marsh and colleagues developed an instrument to assess athletes' perceptions of performance.

The use of a modified version of the EASDQ helped to determine athlete and coach perceptions of an athlete monitoring program by Reed and colleagues (2014). The tool that Reed and colleagues developed focused on the perceptions related to strength and conditioning programs and testing of the student-athlete performances over an academic year. Aspects including skill, aerobic, anaerobic, and performance were included within the questionnaire developed by Reed and worded to meet the question requirements. Reed and colleagues also developed additional questions specific to the services provided by his program.

The validity when applying questionnaires depends on whether the type and range of closed responses reflect the full range of perceptions and feelings that people in all the different potential sampling frames might hold (Boynton & Greenhalgh, 2004). Standardized questionnaires allow all participants to be asked the same questions. However, not all sport teams will use the same testing and monitoring methods. Thus, while general and shared practices should be evaluated, there also needs to be sections where open-ended responses may be completed, distinguishing the unique resources specific teams use. Including more open-ended questions allows for the responses to spread beyond the provided constructs (Reja et al., 2003). A construct is a “hypothesized concept or characteristic (something “constructed”) that a survey or test is designed to measure” despite the limitation of the characteristic not being directly observable (e.g., influence an assessment method) (Artino et al., 2014). Through the application of a “survey scale” (two or more items intended to measure a construct), groups of similar items on a questionnaire are designed to assess the same underlying construct (Robert & DeVellis., 2003). This helps to mitigate a single question influencing an entire construct. Applying a scale enables a more complete, precise, and consistent assessment of the underlying construct (McIver & Carmines., 1981).

Questionnaires: Evaluating Perceptions of an Athlete Monitoring Program

Previous research conducted by Reed and colleagues (2014) sought to determine the reliability and factor loadings of a questionnaire to determine coach and athlete perceptions of an athlete monitoring program throughout an academic year. The athlete monitoring program that Reed assessed was the Sport Performance Enhancement Group program (SPEG), developed through the Center for Excellence in Sport Science and Coach Education (CESSCE) at East Tennessee State University (ETSU). The questionnaire was designed to assess the athlete and coach perceptions of various aspects for the SPEG program. This included aspects related to:

- Overall Performance
- Skill
- Aerobic Endurance
- Anaerobic Endurance
- Strength
- Speed

- Power
- SPEC Testing Understanding
- SPEC Monitoring Understanding
- SPEC Testing Reflecting Performance
- SPEC Monitoring Reflecting Performance
- Data Returned to Athlete

Reed and colleagues developed questionnaires for both the athletes and coaches, with the questions worded for each respective population, with an additional nine questions directed toward the coaches. Eleven total items were included in the questionnaire for the athletes, with questions asking the athletes' perceptions on their overall performance, skill, endurance, repeated sprint ability, physical strength, speed, power, the SPEG data's reflection of their performance, if they understand why they participate in SPEG monitoring (two separate questions), and if their coach provided them with SPEG monitoring results throughout the season. The questionnaire for the coaches consisted of an additional nine questions (including the eleven given to athletes). The additional items of the coaches questionnaire related to the SPEG program assess:

- monitoring data were used to alter an athletes' individual strength and conditioning program,
- monitoring data were considered in practice development, monitoring data reflected athletes on-field performance,
- willingness to use the SPEG program if they were to take a job at another institution,
- the SPEG program helped athletes perform to their greatest potential,
- SPEG program satisfaction, and
- the mode which data was returned to athletes

The tool developed by Reed and colleagues was a modified version of the Elite Athlete Self-Description Questionnaire.

Conclusions drawn by Reed and colleagues from this research found that the modified questionnaire developed was a reliable instrument with a Cronbach's Alpha of 0.842 for athletes and 0.919 for coaches, with the standard of 0.800 getting surpassed by both. Additionally, it was determined that overall positive results from athletes and coaches were obtained from the administered questionnaires. It was partly from these positive results that Reed and colleagues were able to determine if the SPEG program was able to accomplish its goal of enhancing performance over time.

To the author's knowledge, the research conducted by Reed and colleagues (2014) is the only published research of the results from a formal evaluation of an athlete assessment program with a validated questionnaire.

Summary/Conclusion

Assessments, have occurred since the turn of the 19th century, have long been used as a specialized tool that can help to provide a clearer view of the current state of an athlete or a team. New assessment methods continue to develop the robustness of how many common metrics, such as hydration status, anthropometrics, vertical jump height, and strength, are collected and evaluated.

Monitoring athletes requires a performance baseline to be determined to provide context on the measurements obtained during data collection. Baseline measurements establish starting points against which achievable goals set, and testing at regular intervals can help track an athlete's progress toward reaching those goals. Considerations around ensuring these assessment methods are well implemented include:

- prioritizing the health and safety of athlete,
- testers should be carefully selected and trained,
- selected tests and practices of data collection are considered valid,
- tests should be well organized and administered efficiently, and
- athletes should be properly prepared and instructed.

Finally, questionnaires are a viable tool for discerning information about a given topic, serving as an objective method of discerning others' opinions, beliefs, attitudes, and behavior. While questionnaires are customizable to fit individual needs, it is suggested to first find a validated questionnaire prior to putting in the work and research to develop one. Questionnaires have served as effective tools within the world of sport by determining both perceptions of strength & conditioning programs, athlete monitoring, and self-concept that make up performance.

Chapter 3. Evaluating Current Monitoring Practices

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Abstract

Purpose: The primary purpose of this investigation is to evaluate the effectiveness of a questionnaire designed to assess coaches' perceptions of an athlete monitoring program with the secondary purpose of examining the reliability and factor structure of a questionnaire designed to assess coaches' perceptions of an athlete monitoring program. Coaches participating in the athlete monitoring program at East Tennessee State University's (ETSU) Sport Performance Enhancement Group (SPEG) were invited to participate. Reliability for the coach questionnaires was completed after the initial development and use of the questionnaire (22 questions) in the fall of 2023. Nine coaches completed the first two administrations of the questionnaire, which was used to determine its reliability. Eight coaches completed the third questionnaire, and this data was used to determine changes in perspectives over the 14-week term. The questionnaire was reliable (Cronbach's Alpha = 0.953) and can be considered for future use. Perceptions of SPEG by the coaches were determined from the second questionnaire once deemed reliable, with a comparison of the third questionnaire to the second using a Wilcox signed Rank test to determine changes in coaches' perceptions over the fall 2023 term. There were no statistically significant differences between the pre- vs post- questionnaire responses. Considering the range of responses submitted by coaches, this serves as an indicator for the sport scientist/strength & conditioning coach to prompt a dialog with the coach of the team they work with to better understand what else they may contribute towards enhancing the coach's experience with such services.

Keywords: Questionnaire, Performance, Testing, Monitoring

Introduction

Over the past decade, many teams and coaches have turned towards other professionals in sport (i.e., sport scientists and strength & conditioning coaches) to obtain evidence-based knowledge. The goal is to apply this knowledge towards making educated and intentful decisions to enhance the performance outcomes of athletes. Sport scientists are trained professionals, usually with an advanced degree in higher education, who apply scientific theory to sport (French, D., & Ronda., 2021 p. XV; Haff., 2010). These professionals provide the coach with scientifically supported information regarding the training of their athletes. Additionally, sport scientists will seek to obtain data on which their intuition may be based.

Data from athlete monitoring provides useful information toward better understanding whether athletes are responding appropriately to training and competition demands (Thorpe et al., 2017). Sport scientists are faced with an extensive range of technologies to use to obtain data. The data they collect will help them better select the most appropriate variables that are sensitive to fatigue or answer questions coaches may have (Thorton et al., 2019). Additionally, factors practitioners should consider before collecting athlete monitoring data include: how to obtain the data (e.g. logistics, resources), what the potential limitations are of certain variables (e.g. validity, reliability), and how to report the data back to coaches and athletes (Atkinson & Nevill., 1998; Thorton et al., 2019).

One program that seeks to develop such decision-making capabilities in future sport scientist's is the Center of Excellence for sport science and Coach Education (CESSCE), housed at East Tennessee State University (ETSU). The CESSCE oversees the Sports Performance Enhancement Groups (SPEG), a collaborative effort that provide monitoring services for the ETSU and Milligan University athletic programs. The CESSCE has the purpose of creating and disseminating research, providing services to a variety of sports teams, and increasing the preparation of coaches (Center of Excellence for sport science and Coach Education: About, 2011). When sports teams agree to work with the CESSCE, the forming of a SPEG takes place.

The purpose of the SPEG is to bring together sport coaches, sports medicine, strength & conditioning, and sport science to collaborate to obtain data on the team. These data drive the decision-making process of the SPEG and help athletes achieve optimal performance through appropriately implemented training. Periodic testing of the teams throughout each semester help unveil each individual athlete’s abilities and fitness qualities. These abilities and fitness qualities change during each phase of the strength and conditioning program. The tests used to evaluate an athlete’s physical abilities can include tests for: strength, power, speed, agility, aerobic and anaerobic power and endurance. The sport scientists analyzes the data and formulates a report that is presented to the SPEG for discussion as a formal debriefing of findings. Nearly all sports use a basic battery of tests for hydration, body mass and composition, strength and power. Depending upon the characteristics of the sport some teams will perform a different combination of tests/assessments and may also have regular monitoring in place (including GPS and or subjective questionnaires) to meet the evaluation needs of the sport. By assessing these variables, the SPEG can obtain objective and subjective information on how the training process is influencing the performance abilities of the athlete. This approach helps in planning plan future training to maximize the performance potential of each athlete.

Because of the nature of the monitoring program, it is important to determine its perceived effectiveness from the coaching staff since they ultimately decide on how to approach future training. While measures specific to a sport (e.g., runs batted in, passing yards, assists, etc.) may lend insight into an athlete’s specific performance, more general measures (peak force, max speed, and vertical jump height) can serve to measure the effectiveness of a team's physical preparation. However, it is also crucial to determine how these data driven decisions are perceived by the coach. Without the coach viewing the program as a valuable and practical source of performance feedback, it quickly becomes difficult to justify its use.

Therefore, the primary purpose of this investigation is to examine the reliability and factor structure of a questionnaire designed to assess coaches' perceptions of an athlete assessment program. While the SPEG works together to provide guidance, the sport coaches ultimately make the decisions that affect the athletes and the team. Because coaches have the most direct influence on the outcomes, evaluating their perception of the monitoring process is important. There are four reasons for this examination of perceptions: 1) to serve as a check for understanding of how the coach takes in the information presented to them, 2) to identify any gaps in the knowledge of the coach which the sport scientist may help to fill, 3) can serve to open a dialog with the coach for ways in which information may be better tailored to help them improve their decision-making, and 4) the feedback provided can shed insight towards the areas a sport scientist can make more robust (e.g., delivery of information or structure of a training program).

Methods

Participants

Recruitment occurred with NCAA Division I (ETSU) and NAIA (Milligan University) coaches. Only those participating in the SPEG monitoring procedures and over the age of 18 were invited to participate. The total quantity of coaches available for recruitment that met the inclusion criteria was 29. From there, 22 total coaches were recruited to participate in the questionnaire. The final group of coaches included baseball, women's golf, men's soccer, women's soccer, track & field, and weightlifting, a total of 9 participants. All 9 coaches completed the first two rounds of the questionnaire to determine its reliability, with 8 of the 9 coaches in this cohort completing all three questionnaires. This study was approved by the ETSU Institutional Review Board (IRB) and all participants gave their consent to participate in this study (approval #c0723.20e).

Instrument

The questionnaire was designed to assess the coaches' perceptions of various aspects of the athlete monitoring program, especially the testing component. Normally quantitative data on physiological performance is collected during the SPEG program, however, it is of interest for those managing the SPEG program to account for these same variables in the eyes of the coach. This helps to gauge the value that the coaches place on the information derived from the monitoring program. A previously validated tool developed by Reed and colleagues (2014) helped to develop portions of this questionnaire. Additional questions were included to allow for the collection of more information from practitioners regarding the perceptions of the athlete monitoring program. The developed questionnaire was for the coaches to reflect on the current services provided by a SPEG. Additionally, operational definitions for "testing" and "monitoring" were provided so participants could easily distinguish tests used pre- and post- vs daily or weekly. The questionnaire consisted of 22 questions that were either closed questions or an open response option. Closed questions made up 16 of the 22 questions, all of which were on a 5-point Likert-like scale (strongly disagree to strongly agree) with 2 of these 6 questions also having open-ended questions about the types of assessment methods used. An additional option on the Likert-like scale included "NA" for responses where the question may have been non-applicable to the respondent. The last six questions, which were open response option questions, inquired about the method used for data return (team meeting, written report, other coaches, SPEG personnel, or casual coach feedback) and duration of time it took to receive results. For the last four questions on the survey, a blank space was provided for the coach to include a timeframe that may not fit the duration it took for them to receive data.

The questions asked the coaches' perceptions on whether the monitoring data were used to alter an athlete's individual strength and conditioning program (2 questions) (Q 1 & 2), if monitoring data were considered in practice development (2 questions) (Q 3 & 4), their understanding of the monitoring procedures (2 questions) (Q 5 & 6), monitoring data reflected athletes on-field performance (2 questions) (Q 7 & 8), willingness to use the SPEG program if they were to take a job at another institution (Q 9), if the SPEG program helped athletes perform to their greatest potential (Q 10), SPEG program satisfaction (Q 11), reporting data obtained back to the team (Q 12), understanding of the information presented in data reports (Q 13), level of comfort and ability to ask questions to the sport scientist (Q 14 & 15), perception of the reported data getting returned to the other appropriate members on staff (i.e., other coaches, sports med, etc.) (Q 16), the mode of returning data to athletes (2 questions) (Q 17 & 18), duration after data collection that a report was received by the coach (2 questions) (Q 19 & 20), the frequency of data collection (2 questions) (Q 21 & 22).

Data Collection Procedure

Respondents answered the questionnaire on three separate occasions. The first two occurred during the first half of the fall semester after testing each coach's respective team. Coaches received the second questionnaire 48 hours after submitting the first survey. Coaches received questionnaire three towards the last month of the term. Each questionnaire was completed electronically on Google Forms. A total of 18 responses were possible for coaches from pre- to postseason, with 17 responses received ending with a 94.4% response rate.

Statistical Analysis

Obtained data from Google forms was organized in Microsoft Excel, then read into R, version 4.3.20 (R Core Team, Vienna, Austria; https://www.R-project.org). Cronbach's Alpha determined the reliability of the questionnaire. A Wilcox Signed-Ranked test assessed coaches' changes in perceptions over the course of the Fall term, with the statistical significance set at $p<0.05$. Listed in Table 3.1 are the effect sizes (r) for all time points and are calculated using Hedge's *g*.

Results

Reliability analysis was conducted on the responses of nine participants, this was performed on a pair of questionnaires that were separated by a period of 48 hours. A Cronbach's Alpha of 0.953 ($p <0.008$, 95% CI 0.93 – 0.97) indicated that the coach questionnaire is reliable since it is above the standard 0.800. The two separate instances assessed changes in perceptions throughout the Fall term. Constructs in the first column of Table 3.1 are the combined questions that pertain to similar topics. *Testing Influence* combined questions 1 and 3, *Monitoring Influence* combined questions 2 and 4, *Overall Understanding* combined questions 5 and 6, *Reflecting Performance* combined questions 7 and 8, *Applicability* combined questions 9, 10, and 11, *Returning Data* combined questions 12, 13, 14, 15, and 16, *Timeliness* combined questions 19 and 20, and *Frequency of Data Collection* combined questions 21 and 22. None of the constructs demonstrated statistically significant differences when compared pre to post.

Table 3.1.

Mean, Standard Deviation, Significance, and Effect Size for Coach Questions

Construct	**Pre**		**Post**		**Sig. (p < 0.05)**	**Effect Size**
	M	***SD***	***M***	***SD***		
Testing Influence	3.69	1.04	3.88	0.90	0.81	0.08
Monitoring Influence	3.43	1.56	3.86	1.05	0.97	0.01
Overall Understanding	3.99	1.10	4.39	0.65	0.98	0.01
Reflecting Performance	3.60	1.23	3.86	0.85	0.97	0.01
Applicability	3.88	1.37	3.83	0.94	0.37	0.32
Returning Data	4.45	1.44	4.38	1.44	0.33	0.35
Timeliness	3.09	1.21	3.55	1.34	0.50	0.31
Frequency of Data Collection	3.86	1.04	3.86	0.81	0.81	0.17
Primary Mode Data was Returned	Written Report (6) and Monitoring Personnel (2)		Written Report (6) and Monitoring Personnel (2)		1.00	0.00

Table 3.2.

Timeliness and Frequency of Data Collection Quantification

Timeliness				**Frequency of Data Collection**			
Testing		**Monitoring**		**Testing**		**Monitoring**	
Return Timeframe	**Quantified Score**	**Return Timeframe**	**Quantified Score**	**Return Timeframe**	**Quantified Score**	**Return Timeframe**	**Quantified Score**
Within 48 hours	5	Within 4-6 hours of practice	5	5-6 times a year	5	Daily	5
48 hours - 1 Week	3.75	Within 2-4 hours of practice	3.34	3-4 times a year	3.34	Weekly	2.5
1-2 Weeks	2.5	Within 1 hour of practice	1.67	1-2 times a year	1.67	Not applicable	0
2-3 Weeks	1.25	Not applicable	0				

Table 3.3.

Timeliness and Frequency of Data Collection Outcomes

Timeliness						**Frequency of Data Collection**					
Testing			**Monitoring**			**Testing**			**Monitoring**		
Return Timeframe	**Pre**	**Post**	**Return Timeframe**	**Pre**	**Post**	**Return Timeframe**	**Pre**	**Post**	**Return Timeframe**	**Pre**	**Post**
Within 48 hours	1	2	Within 4-6 hours of practice	1	2	5-6 times a year	1	0	Daily	5	5
48 hours - 1 Week	3	3	Within 2-4 hours of practice	3	2	3-4 times a year	5	7	Weekly	1	1
1-2 Weeks	3	2	Within 1 hour of practice	2	1	1-2 times a year	2	1	Not applicable	2	2
2-3 Weeks	1	1	Not applicable	2	3						

Discussion

Validating the Tool

The investigators sought to determine the reliability and factor loadings of a questionnaire and determine coach perceptions of an athlete assessment program throughout a term. Reliability was assessed at the beginning of Fall 2023. Results for the instrument indicated an overall ICC reliability of 0.953, which is above the standard of 0.800. Therefore, this modified instrument is reliable and may have use in future investigations.

Timeliness and frequency of data collection are two variables that are simplified from the previous survey (Reed) from Likert scale to numbers. The responses are weighted so that the earlier the information was received by the coach the higher the response scored. Responses for *Timeliness* related to the return of data following testing. This construct consisted of four timeframes with an additional open response answer if a timeframe did not match any available options, while monitoring had a fifth response if the question was not applicable. Responses for *Frequency of Data Collection* consisted of three timeframes for testing with an additional open response answer if a timeframe did not match any available options, while monitoring had only two timeframes, a “Not applicable” option, and an additional open response answer if a timeframe was not applicable. The weight of each response was determined by the number of available responses, then divided by 5 to generate the points for each response. Table 3.2 indicates the value of each response for questions 19-22. Table 3.3 shows the number of responses from questions the participants answered.

Testing results from the *Timeliness* construct showed improvement, though not statistically, from the beginning of the term to the end, with more data getting returned to coaches in one week following SPEG testing. The results from the *Frequency of Data Collection* construct as it relates to testing indicated a shift towards 3-4 testing sessions per year, a typical approach to pre and post testing that would match up with the beginning and end of each term. Monitoring results from the *Timeliness* construct showed an increase in the time it took to present data to the coach from the beginning of the term to the end. This can occur for several reasons but is overall optimal since this gives the coach more time to plan accordingly based on the information they receive. The results from the *Frequency of Data Collection* construct regarding monitoring indicated no change between the beginning and end of each term. Since most respondents indicated that daily monitoring was used, this aligns with the benefit of making regular adjustments towards approaching practices during the week.

Questionnaire Outcomes

Two of the four reasons perceptions examined with this questionnaire were able to get answered: 3) can serve to open a dialog with the coach for ways in which the information may be better tailored to help them improve their decision-making, and 4) the feedback provided can shed insight towards the areas a sport scientist can make more robust (e.g., delivery of information or structure of a training program).

To check the coaches' understanding of how information was presented to them, constructs related to the influence of testing and monitoring, overall understanding, and reflecting performance were examined further. The influence of testing (Q 1 + 3), the influence of monitoring (Q 2 + 4), and the assessments represented athlete performances (Q 7 + 8) fell into the neutral/agree range, indicating they are adequate but may be improved upon. The primary mode that data is returned can impact the influence of monitoring as they relate to structuring practices and strength & conditioning sessions. Six of the eight respondents indicated that a written report was the primary method data was delivered back to the coaches. It may be worthwhile to include more context in these written reports on how the acquired results of the assessments can be applied back to training sessions. A follow-up in-person from the sport scientist, in addition to a written report, can provide additional context to the coach. Additionally, the coach now has the opportunity to ask questions about effectively implementing appropriate training methods, and the sport scientist can share insights towards approaching training. In regard to improving how the assessments relate to performance, this also depends on the amount of context the coach has on the monitoring that is conducted and/or the specificity of each assessment. If coaches receive information from the sport scientist on how the selected testing (e.g., hydration, body comp. [bioelectrical impedance], jumps [static, countermovement, weighted, and unweighted], and isometric mid-thigh pulls) relate back to strength & conditioning or sport-specific performance, then the coach can better understand with the additional context how these assessments reflect performance.

The gaps of knowledge identified by this questionnaire should be related back to each coach individually. The reason for this is due to the range of responses reported across the constructs. There were coaches who had their responses exclusively vary between “agree” and “strongly agree”, while others would only vary between “disagree” and “strongly disagree” on the Likert responses. Therefore, knowledge gaps across the different constructs are best to address with each individual coach, rather than generalize across all who participate. This approach allows for individual consideration to be made across the constructs to better plan and approach future assessments. Frequent constructs where there were gaps in the knowledge included how monitoring data influenced strength & conditioning and practices (Q 2 + 4), and how testing procedures reflect athletes’ on-field performance (Q 7 + 8).

Feedback from the questionnaire to help open a dialog with the coaches relates to overall understanding (Q 5 + 6), reflecting performance (Q 7 + 8), and returning data (Q 13-16). “Overall understanding” questions help identify the coaches’ knowledge of why the assessments are selected. This helps the sport scientist identify if there are assessments used regularly or pre-to-post that can be better comprehended by the coach, so the measurements obtained lead to better planning of training. Examining the outcomes of previous questions allows for this construct to receive further examination and to identify whether testing and/or monitoring for strength & conditioning and/or practice development needs to be clarified for the coach. “Reflecting performance” questions help identify how each coach perceived the athletes’ on-field performance relative to information acquired from the assessment(s). Practice structure can receive modifications if assessments can effectively determine the current performance capabilities of the athletes, with the goal of enhancing training outcomes. This decision-making can also relate back to strength & conditioning and how training method in that setting can benefit on-field performance. “Returning data” questions help to identify if the coach understands the information that is delivered to them in a written report or an in-person data return. By evaluating the coaches’ level of comfort this may determine if further dialogue is needed and for the sport scientist to ask if the coach has further questions. To enhance the effectiveness a data return has on the coach’s decision-making, relevant metrics should be included and regular checks for the coaches’ understanding take place to help them understand the information further.

Areas the sport scientist can make more robust based on the feedback from the questionnaire relate to monitoring influence (Q 1-4), overall understanding (Q 5 + 6), reflecting performance (Q 7 + 8), and returning data (Q 13-16). As previously noted, how the data is delivered, sharing with coaches the purpose of each assessment throughout the data collection and return process can be improved. This refinement includes assessments specific to on field performance and implemented training methodology. Allowing for the sport scientist to be approached with further questions from the coach to clarify and share additional context are all means that the current system the coaches work with can be improved upon.

Coaches who participated in the questionnaire came from various involvement with the SPEG. Some coaches began working with the CESSCE in the past year, so the whole process was new to them. This may explain instances where there were low scores related to understanding. Another potential factor that may relate to the outcomes of scores is whether the sport scientist that was working with the coach recently began to collaborate with them and their team. This may indicate that the working relationship between these two professionals is still developing. Finally, some coaches may not be as involved with the SPEG process. The reason for this is that the coach may have much of their time dedicated towards the planning logistics for their respective team and entrust the decision-making related to strength & conditioning to the sport scientist.

Comparing this modified questionnaire to the tool that it was adapted from, developed by Reed and colleagues (2014), there are a number of similarities and distinct differences. Similarities include questions 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, and 20 from Reed's questionnaire, which match up with questions 1, 2, 3, 4, 5, 6, 7, 8 , 9, 10, 11, 12, and 17 from the questionnaire used in this research. Additionally, the same rating on the Likert-scale was used, this allowed for coaches to follow a simple rating system and also have the option to indicate the question was not applicable to them. This is valuable since, depending on the team, each sport would have different needs and may only test their athletes at the beginning and end of the term, rather than monitor daily information in addition to occasional testing. Differences that exist between the questionnaires include the additional questions, conducting an analysis of questionnaire results from the sample based on constructs rather than single questions, and providing additional information to the coaches on operational definitions (i.e., monitoring). A construct is a "hypothesized concept or characteristic, something "constructed", that a survey or test is designed to measure" despite the limitation of characteristic not being directly observable, e.g., influence of an assessment method (Artino et al., 2014). Through the application of a "survey scale", two or more items intended to measure a construct, groups of similar items on a questionnaire designed to assess the same underlying construct are developed (Robert & DeVellis., 2003). This allows for no single question to influence an entire construct. Applying a scale enables a more complete, precise, and consistent assessment of the underlying construct (McIver & Carmines., 1981). Questions that did not exist in the previous tool developed by Reed related to returning the data (questions 13, 14, 15, and 16), how soon after data collection was information returned to the coach (questions 19 and 20), and how frequently data collection occurred (21 and 22). The goal of including these additional questions was to determine if coaches were receiving information promptly enough to make informed decisions. Operational definitions of both “testing” and “monitoring” provided early in the questionnaire were to help coaches distinguish the data collection methods their team utilized. The inclusion of these definitions was in an effort to mitigate the frequent interchangeable nature of these terms and help the coach appropriately identify what each question was asking. Finally, Reed and colleagues (2014) initially sought to assess perspectives from both athletes and coaches. While it may be beneficial to gain insight into the perspectives athletes have to better address and accommodate their experiences, it is ultimately the coach who will make decisions based on the provided information. The coach’s decisions can influence practice structure, training approaches for specific athletes, and addressing additional needs to positively impact performance outcomes.

The results from this modified questionnaire compared to the questionnaire developed by Reed and colleagues (2014) showed differences in perceptions pre to post. Shared constructs between the two questionnaires resulted with Reed’s questionnaire containing higher initial scores that declined during the term, while the current questionnaire experienced an increase in the scores by the end of the term. Shared constructs between the two questionnaires consisted of testing influence, monitoring influence, understanding, reflecting performance, and applicability. Related to “*testing influence*”, we found it initially rated between a “neutral” and “agree” (3.69) before a non-statistically significant increase of the rating occurred at the end of the term (3.88). At the same tile, Reed showed a decline in “*testing influence* over time (4.21 down to 3.6). The reason for this discrepancy might be due to poor outcomes the team experienced as the season went on or data returned to the coaches did not meet their expectations. Related to “*monitoring* *influence*”, we found it initially rated between a “neutral” and “agree” (3.42) before a non-statistically significant increase of the rating occurred at the end of the term (3.86), while Reed showed a decline in “*monitoring influence*” over time (4.0 down to 3.6). The reason for this discrepancy might be due to how the monitoring data impacted decision making at the end of the term, with poor team performances potentially being attributed to the quality of data that was received. Related to “*overall understanding*”, we found it initially rated as “agree” (3.99) before a non-statistically significant increase in the rating occurred at the end of the term (4.39), while Reed showed a decline in “*overall understanding*” over time (4.45 down to 4.4). The reason for this discrepancy might be attributed to the data returned to the coaches and the sharing method for information (e.g. written report or in person debriefing). If this information was not coherent and sufficiently elaborated upon, then the coach may have struggled to comprehend the outcomes. Related to “*reflecting performance*”, we found it initially rated directly between a “neutral” and “agree” (3.6) before a non-statistically significant increase in the rating occurred at the end of the term (3.86), while Reed showed a decline in “*reflecting performance*” over time (4.0 down to 3.2). The reason for this discrepancy might be due to the selected assessment not reflecting the performance outcomes the coach expected or the transferability of general assessments (e.g., jump and IMTPs) was not apparent. Related to “applicability”, we found it initially rated between a “neutral” and “agree” (3.88) before a non-statistically significant decrease of the rating occurred at the end of the term (3.83), while Reed showed a decline in “applicability” over time (4.13 down to 3.73). The reason for this discrepancy might be due to the team’s success as the season went on was poor or the data returned to the coaches was not understood, causing a lack of understanding reflected with a lower score.

Generally, Reed (et al., 2014) speculated that the drop-off experienced for his results pre to post could be heavily-influenced by the outcome of the season each team experienced and how the SPEG program was explained. While the soccer coaches that participated in this study had successful seasons along with improved perspectives on the final questionnaire, there were also coaches on teams who were in the off-season whose perspectives improved on the final questionnaire as well. While results pre to post could be heavily influenced by the outcome of the season each team experienced, more teams need to be present in the study to come to a similar conclusion. Reed also suggested that strength and conditioning personnel provide explanations of the factors that can be influenced with this approach to training. This is a simple approach to share information with the coaches so they may have a clear representation of the program's abilities. Finally, Reed believed that while the training program was being described to the coaches, there may be instances where the program's influences on performance were misinterpreted. To reduce the instances where misinterpretations may occur, examining the results from specific coaches who completed the questionnaire used in this study may provide a useful understanding of how the coach perceived the information. While it would be interesting to compare changes in sports over time, coaches that participated in Reed's study were from women's basketball and women's volleyball, sharing no overlap with current coaches who participated.

Conclusion and Practical Application

Overall, the coaches were in agreement with or neutral to the questions regarding the influence and understanding of the data as well as how the assessments that were conducted reflected the performance capabilities of their athletes. No statistical differences were present in the coaches' perception of the influence of both monitoring, understanding, or how the results from the performance assessments reflected performance. There were no statistical differences in how applicable coaches found the information, the effectiveness of the mode to return data, how soon following data collection the coach received information, or how often collection of data occurred. Finally, the primary way data was returned to the coaches occurred via written reports (6 of 8). The remaining data came directly from the Monitoring Personnel (2 of 8). This insight is important since a written report better allows the coach to review key points of information delivered to them and also prompts further questions from the sport scientist/strength & conditioning coach they are working with. Other methods to deliver information (e.g., team meetings, in passing, or from other coaches) might occur less often due to time constraints that inhibit their use, and the delivered information may be poorly retained. It is important for personnel within an athlete monitoring program to understand the potential performance outcomes of the athletes they work with when implementing strength and conditioning practices with them. When explaining performance alterations and suggestions for approaching training to the coaches, decisions based on the athlete's current status are necessary for maximizing performance and competitive outcomes.

A limitation of this study was that only a limited sample participated from the available population and diversity among that sample consisted of only ETSU coaches. While invited to participate in the questionnaire, no coaches from Milligan University followed up to partake in the study. The limitation of the sample may be justified by the already limited population of participants who met the criteria for inclusion. In future research, larger samples may help to better understand the differences between men's and women's sports as well as individual and team sports. The second limitation may also be partially justified, since the athlete assessment program is conducted on ETSU's campus and, while Milligan University does participate in testing sessions through the SPEG program, do not share the same campus. So, the distance and reduced exposure may have limited the interest of those coaches in participating.

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Chapter 4. Considering the Approach to Your Assessments

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Abstract

Purpose: The goal of this section is to provide practitioners who are interested in developing a program to assess their athletes with resources to better approach the logistics for developing their own system. When initially approaching an assessment program, it is necessary to begin with considerations for structuring the system prior to collecting data.

Part I

Evidence-Based Practice, how to critically approach research to enhance performance outcomes.

Part II

Precursors to Data Collection: pre-testing certifications, lab set up, data collection, and testing protocols. This includes medical clearance and considerations for how the testing session will run. From there, where the data will get collected (laboratory vs field), knowing what tests you plan to conduct, and ensuring the athletes are adequately prepared and familiarized with the protocol.

Part III

Approaching Data Collection: addresses factors related to assessments, athletes, and additional considerations. Factors related to assessments cover the quantity and quality of the staff collecting the data, cost and selection of equipment, time, the environment, and data management. Factors related to athletes cover the fatigue accumulated from previous tests or training, the athlete's knowledge of the assessment, their ability to give maximal effort as well as remain motivated throughout data collection. Additional considerations cover aspects of assessment validity and reliability.

Part IV

Potential Assessment Methods to Consider: Assessing hydration, body composition, vertical jump height (VJH, kinetics and kinematics), and maximal strength. Tests focus on determining hydration status, body composition, vertical jump height, and maximal strength capabilities are covered in regard to the various ways each method may be assessed, the gold standard, logistical considerations (cost, time, personnel training, etc.), and common metrics each tool provides.

Keywords: monitoring, testing, hydration, body composition, jump height, peak force

Introduction

The value of monitoring athletes holds many benefits. These assessment modalities can help to determine program efficacy, levels of preparedness, and fatigue. Assessments function as a means of evaluating athletic talent, identifying physical abilities, and areas in need of improvement (McGuigan, 2016a). Monitoring can be divided into program efficacy and fatigue management, which help practitioners engage in better decision-making. Program efficacy is necessary since encompasses a process for evaluating training methods and modalities to determine their effectiveness in producing alterations in physical, psychological, and performance characteristics. Specifically, "if accurate and easy to interpret feedback is provided to the athlete and coach, load monitoring can result in enhanced knowledge of potential training responses, aid in the design of training programs, provide a further avenue for communication between support staff, athletes, and coaches with the end goal of enhancing an athlete's performance" (Halson., 2014). Fatigue management encompasses day-to-day estimates of energy expenditure and recovery (Stone et al., 2007). The goal of fatigue management is to manipulate the training program variables (i.e., intensity, volume, and frequency of training) and the training process in an effort to increase the likelihood of decrease the likelihood of overstress, non-functional overreaching or overtraining, so, adaptation is not impeded. Additionally, by monitoring the training load of an athlete, insights into fatigue management effectiveness can be provided (Halson & Jeukendrup, 2004). Although there can be some overlap with fatigue management, program efficacy is focused on determining if each training phase or the program as a whole was able to produce the expected results (Stone et al., 2007). The purpose of monitoring programs is to have an emphasis towards research and particularly application of the information obtained (Stone et al., 2007 ; Stone et al., 2022b). This allows for the gathering of valuable information to then provide insight into future approaches to develop the athlete through training.

When developing the approach to assessment implementation, it is important to take into consideration items that relate to sport specificity (e.g., metabolic energy systems or biomechanical movement patterns), athlete experience, training status, age, and environmental factors when selecting tests (MacDougall et al., 1991; McGuigan, 2016a; Stone et al. 2022; Tanner & Gore., 2012). Metabolic energy systems and the athlete's position within a sport (e.g., forward, defender, goalie, quarterback, etc.) should be considered when applying the principle of specificity when choosing or designing valid tests to measure athletic ability for specific sports (Buchheit & Laursen., 2013, Fox et al., 1993., Joyce & Stewart., 2014., Turner, A. N. & Stewart., 2013). If a well-trained and experienced athlete is assessed, then a technique-intensive test may be appropriate for more sport specificity (McGuigan, 2016a).

Evidence-Based Practice

Over the past 15 years, the field of strength & conditioning has begun to adopt the use of evidence-based practice (EBP) to ensure sound approaches towards developing athletes (Coutts., 2017; Jefferys., 2015). While not all practitioners in the field apply this method, best practices will frequently draw from multiple reliable resources in order to draw developed conclusions/approaches. Broadly, the goal of EBP is to enhance the quality of interventions by encouraging practitioners in a range of related fields to provide evidence to support or reject specific interventions (Jefferys., 2015). One application of EBP was introduced in the early 1990s as a means for clinical medical practices to apply a systematic approach based on principles of evidence, professional reasoning, and patient/client preferences to better the outcomes in healthcare (Sackett et al., 1996; Thomas et al., 2011). Applying EBP to the strength

& conditioning setting can be accomplished by having the previously listed principles apply to research-based evidence, the coach's experience/judgements, and the preferences/constraints of the environment (Jefferys., 2015). Effective integration of EBP in strength and conditioning may "improve training and performance, reduce training errors (e.g., injuries or inappropriate training), help balance known benefits and risks in decision-making, challenge belief-based views with evidence, and integrate athlete and coach preferences into decision-making around approaches to training and performance" (Coutts., 2017). An approach of simplifying the complexity of a sport down to its key features is frequently undertaken by sport scientists. Once these features are identified, then focus may be directed toward a range of variables that can explain essential aspects of performance (Jeffreys., 2015). While these variables are identified, the application of science should help to better understand sport and aid in guiding our decisions rather than solely focus on obtaining optimal outcomes of specific metrics. Specifically, strength & conditioning will benefit greatest from EBP when managing the probability of an intervention being successful through the well-thought-out application of an input that aims to maximize the probability of success (Jefferys., 2015).

The rationale for having an assessment program tied to an athletic program is to insure the best possible intervention is applied to the current performance goals of a team. Depending upon performance assessment outcomes related to strength, power, and specific metrics related to their sport, then future training sessions can receive necessary changes to better allow for enhanced physical development. Metrics such as strength (force production i.e., Newton) and power (work-rate i.e., Watt) apply to general (in addition to specific e.g., power lifting or weightlifting) performance outcomes and are frequently enhanced through strength and conditioning. More specific performance metrics (e.g. VO_{2max}, reaction time, or pitch speed) apply towards specific performance outcomes in a sport and can be enhanced through conditioning modalities or sport-specific training. Sport-specific training occurs when adaptations to enhance performance are achieved by directly training or competing with the sport (e.g., ice hockey, soccer, swimming, sprinting, etc.). An assessment program benefits athletic programs immensely through properly identifying where the current athlete performance capabilities, then applying EBP to further the development of skill components that relate back to the demands of the sport. Application of an EBP approach works most effectively when coaches, support staff, athletes, and researchers, work together through this process to discern the most effective method for a given situation (Coutts., 2017). It is always best to share the reasoning for the implementation of the chosen EBP with the other staff who are involved in the training process. Appropriate application of EBP also requires the critical observation and evaluation of environmental constraints within an athletic program (e.g., training facilities, accountable hours, travel/competition schedule, academic obligations, etc.).

Precursors to Data Collection

Informing the athletes as to the purpose of the assessments that they will participate in should take place before the athletes go through familiarization of how to perform the test(s). This is an opportunity to educate the athletes on what you plan to do and how this can benefit their future performance outcomes related to program efficacy and fatigue management. Some essential components toward this informational meeting should include record keeping of who was there, providing a handout of key points, elaborating on the points covered in the handout, and allowing time for questions (Gray., 2024). Keeping track of who attended the meeting ensures that you will be able to appropriately inform all participating in the tests, while also acting as a contingency in case athletes have a poor recollection of the information they received.

Additionally, a handout outlining the important points accompanied by a formal briefing that elaborates on these points will serve to expand the athletes' knowledge of the testing and why it is important. Finally, providing athletes the chance to ask questions at the end will ensure they receive adequate context to help them comprehend the information.

Obtaining informed consent is a necessary step prior to acquiring data from athletes whose results will be used for research. Research, in this case, relates to publications or presentations of information about the athlete's performance or their specific characteristics outside of the intent to develop their performance outcomes (Human Research Protection Program., 2023a). This is when an informed consent document (ICD) is drafted, reviewed, approved, and implemented. Effectively implementing an informed consent process should take the following into consideration. First, consider conducting the process in a manner and location that ensures participant or group privacy, such as a classroom, office, or conference room (Human Research Protection Program., 2023a). Next, it is necessary to provide an adequate amount of information about the study to the potential participant in a language they can comprehend (Human Research Protection Program., 2023a). Impairments that may limit the ability to comprehend adequately include illness, intoxication, drunkenness, using drugs, insufficient sleep, and other health problems. Then, throughout the process, the potential participant is provided with an adequate opportunity to consider all options on the risks and what the research process will entail (Human Research Protection Program., 2023a). Finally, it is necessary to address any questions or concerns the potential participant may have (Human Research Protection Program., 2023a). The potential participants' informed consent must be given freely, without coercion, and must be based on a clear understanding of what participation involves (Human Research Protection Program., 2023a). In some cases, consent of someone on behalf of a person not considered able to give informed consent is valid, such as when a parent(s) or legal guardian(s) of a child and caregivers for the mentally ill provided their consent on top of the one they are providing guardianship of (Human Research Protection Program., 2023b).

Medical clearance is another essential consideration before performance assessments take place. Athletes should receive medical clearance before physical training and competition. Strength and conditioning professionals must be aware of testing conditions that can threaten the health of athletes and be observant of signs and symptoms of health problems that warrant exclusion from testing (Fox et al.,1993; Fukuda., 2019). This is accomplished with a preparticipation physical examination, which has the goal of detecting the athlete's injuries, illness, or any factors that may place the athlete or others at risk (Chrisostomidis., 2009). During training sessions, a medical referral may be necessary if an athlete has/indicates any of the following symptoms: "chest pressure, pain, or discomfort; listlessness; light-headedness; dizziness; confusion; headache; deeply reddened or cold and clammy skin; irregular pulse; bone or joint pain; blurred vision; nausea; or shortness of breath, rapid pulse, or weakness either not commensurate with the level of exertion or unresponsive to rest" (McGuigan, 2016a). To maintain the health and safety of athletes, testers should be carefully selected and trained, assessments should be well organized and administered efficiently, and athletes should be properly prepared and instructed. (McGuigan, 2016a).

Approaching Data Collection

Factors Related to the Assessment

When implementing monitoring protocols, it is important to determine the factors that will impact the assessment. This includes (but is not limited to) the quantity and quality of the staff collecting the data, cost and selection of equipment, time, the environment, and data management.

Personnel that staff the testing session should have received enough training to be proficient with overseeing the assessment they conduct. First, the staff acquiring data should be informed of any standardized protocols in the assessment process and common mistakes or issues that may arise with each assessment (Fukuda., 2019). Having staff that are trained and knowledgeable about the monitoring that is taking place is essential. This ensures tests have strong reliability with how the athletes are set up, the cues used to get the athletes prepared, and how the data is collected. Typically, a script is provided to testers in advance and during the assessment which outlines the simplified language to explain the assessment (Fukuda., 2019). This helps to ensure a better understanding from the athlete of what is expected. Test administrators should be well trained and have a thorough understanding of all testing procedures and protocols. Training should include ensuring the tester can explain and administer the assessments as consistently as possible. This often requires sufficient practice so that the scores they obtain correlate closely with those produced by experienced and reliable personnel (McGuigan, 2016a). Having enough staff to conduct data collection, especially if multiple stations are involved, helps to ensure that athletes move smoothly through the procedures in as little time as possible (McGuigan, 2016a). This factor is important since some organizations, such as the NCAA, limit contact hours, and athletes can participate in events based around their sport each week (NCAA Bylaw 17.1.5.1). Efficiently moving many athletes through a session may be accomplished by having one tester alternate between two testing stations to avoid wasting time as athletes get ready (McGuigan, 2016a). Finally, test planning must address whether athletes will be tested all at once or in groups and whether the same person will administer a given test to all athletes (McGuigan, 2016a). The main consideration is the number of athletes tested. It is preferable to have the same person administer a given test if time and schedules permit, because this eliminates the issue of interrater reliability (McGuigan, 2016a).

The cost and selection of equipment is another important factor to consider. While it is ideal to use the gold standard for an assessment, this method is usually costly and may be outside of budget for an organization/program. Decision-making should be driven by the cost of the equipment, the needs of the coach or fitness professional, the available budget, and the amount of technology expertise and support (Fukuda., 2019). When high-cost options are not feasible, alternative methods of assessment that are still reliable can be purchased. An example of this is with body composition, where DEXA (considered the gold standard) is research grade equipment with each assessment costing several hundred dollars compared to skinfolds, a far cheaper alternative. While more data may be obtained from DEXA, the cost of skinfold assessments, especially if a proficient tester is present, can still obtain valuable data at the cost of the calipers and their maintenance. Additionally, equipment should be well clean and receive maintenance, when possible, to ensure the safety of those using it (Hudy., 2016). This helps to prolong the use of the equipment so it may continue to function at a high standard while saving additional costs on replacements (Fukuda., 2019). Finally, Fukuda (2019) developed a basic facility and equipment safety checklist, which is a tool that covers many of the necessary considerations related to the proper care of users and equipment in a testing space.

The duration of the assessments is important to consider since many organizations have limitations for the quantity of contact hours a team has over a week. Essential considerations include the time needed for each assessment (this includes rest and recovery time), the number of sessions and assessments that make up each session that takes place, the number of athletes that are scheduled for assessment, and the order of assessment (Fukuda., 2019). Multiple sessions should be scheduled if the total time needed to complete selected assessments is longer than the time available (Fukuda., 2019). Time limits may occur due to training schedules (assessments can adversely affect training and vice versa if occurring too closely), the availability of the athlete, and the availability of facilities and staff/personnel (Fukuda., 2019). Assessments should follow one another immediately yet allow for adequate rest, so the athlete does not need to wait long between stations. If there are assessments conducted with multiple athletes going at once or cycling through (e.g., yo-yo, Sargent jump test, sprints, or 505), then getting enough of the team to participate while not limiting the personnel's ability to obtain data is the best approach for running several athletes simultaneously.

When preparing to acquire data from athletes, it is important to consider where the testing is taking place and the potential limitations of the setting. Data collection can take place in a laboratory setting where there is usually more control over the environment, or there is field testing which can be more specific to the conditions the athlete will typically encounter. Field tests can serve as a tool for coaches to assess necessary basic physical abilities and the technique and training practice that could produce a competitive player (McGuigan, 2016a). Field tests often have higher ecological validity when compared to testing that takes place in the lab and may accurately gauge the progress of fitness and establish accurate training recommendations (Russ., 2015). This may get confused with testing in the field, which occurs when a test is used to assess ability that is performed away from the laboratory and does not require extensive training or expensive equipment (Chu & Vermeil., 1983). However, the laboratory setting is more controlled, usually allowing for greater reliability of results from multiple data collection sessions. Testing should take place inside when possible to control the climate. Since environmental factors such as temperature, humidity, altitude, noise, and lighting can influence performance outcomes (Fukuda., 2019). High ambient temperature, especially in combination with high humidity, can impair endurance exercise performance, pose health risks, and lower the validity of an aerobic endurance exercise test. Aerobic endurance performance (Parkin et al., 1999; Sparks et al., 2005) and intermittent sprint performance (Hayes et al., 2014) may be impaired when the temperature approaches 80 °F, especially if the humidity exceeds 50% (Kraning & Gonzalez., 1997). If indoor conditions are not available or feasible, it is good practice to measure and document the environmental conditions and then to consider these factors when interpreting the results. Altitude is a factor that can also impair performance on aerobic endurance tests, although not on tests of strength and power (Baumgartner & Jackson., 1998). Norms on aerobic endurance tests should be adjusted when testing at altitudes exceeding 1,900 feet (580 m). Up to about 9,000 feet (2 ,740 m), maximal oxygen uptake declines by approximately 5% for each 3,000 feet (910 m) of elevation. At even higher altitudes, maximal oxygen uptake declines more sharply. Athletes who arrive at a relatively high altitude after living near sea level for an extended period of time should be given at least 10 days to acclimate before undergoing aerobic endurance tests (Schuler et al., 2007).

Finally, data management is a critical consideration that needs to be thought about in advance, so an effective system is in place when data is collected. A data management plan (DMP) should provide you and other practitioners with an easy-to-follow overview of the system and its components to help guide and explain how data are treated throughout the process of collection, storage, and future use (Michener., 2015). Aspects of a data management system should include identifiers for the collected data, define how the data will be organized, explain how the data will be documented, describe how data quality will be assured, present a sound data storage and preservation strategy, describe how the data will be disseminated, and assign roles and responsibilities (Michener., 2015).

When identifying the data that you will collect, factors such as the quantity as well as the type of data are necessary to know. In regard to the quantity of data, having the infrastructure and personnel for appropriate management should be considered in addition to the cost of housing the data (Michener., 2015). The nature of the data will include its type (i.e., text, spreadsheets, software and algorithms, models, images, etc.), sources (i.e., direct human observation, laboratory and field instruments, experiments, simulations, etc.), volume (i.e., total volume and number of files), and file formats (preferably uncompressed, unencrypted, and stored using standard character encodings) (Michener., 2015).

When explaining how the data will be documented, details about what, where, when, why, and how the data were collected, processed, and interpreted, can provide the information that enables data and files to be discovered, used, and properly cited (Michener., 2015). This is often referred to as metadata, which includes essential details of how data and files are named, physically structured, and stored and details about the experiments, analytical methods, and research context (Michener., 2015). Describing how data quality will be assured is approached by measuring, assessing, and improving the quality of products (Michener., 2015).

Next, it is imperative that there is a sound data storage and preservation strategy in place. Simply, this may be accomplished by duplicating data that is acquired and archiving data in a secure location for the long term (Michener., 2015). More tangible methods such as papers, hard disks, URLs, tapes, and other media have an expiration that should be considered if implemented and should not be the sole means of retaining data. Important questions to answer include: “How long will the data be accessible”, “How will data be stored and protected over the duration of the project”, and “How will data be preserved and made available for future use” (Michener., 2015). Sound practices such as storing at least three copies in at least two geographically distributed locations (e.g., original location such as a desktop computer, an external hard drive, and one or more remote sites), have a regular schedule for duplicating the data, and being able to access the data 20 years beyond the life of the project will contribute immensely towards having data safely accessible (Michener., 2015).

The ways in which data will be disseminated are important to include in the DMP as well. This can be broken down into passive and active methods. Passive approaches for dissemination data include posting data on a project or personal website in addition to mailing or emailing data upon request (Michener., 2015). Active approaches are considered to be more robust and include publishing the data in an open repository or archive, submitting the data (or the final product that illustrates the data) as appendices or supplements to journal articles, and publishing the data, metadata, and relevant code (Chavan & Penev., 2011).

Finally, assigning roles and responsibilities of every named individual and organization associated with the project is the last necessary step towards the management of data (Michener., 2015). Here it is necessary to consider time allocations and levels of expertise needed by staff since their roles will include data collection, data entry, quality assurance and quality control, metadata creation and management, backup, data preparation and submission to an archive, and systems administration (Michener., 2015). The staff can be one person if the project is small or an entire team of dedicated staff. It is good practice for the staff member(s) to track any changes in a revision history that lists the dates that any changes were made to the plan along with the details about those changes, including who made them (Michener., 2015).

Factors Related to Athletes

Additional factors related to athletes' performance on the assessments should be considered and implemented within monitoring protocols. This includes (but is not limited to) items such as the fatigue accumulated from previous tests or training, the athlete's knowledge of the assessment, their ability to give maximal effort and their motivation throughout data collection.

The fatigue experienced by athletes during an assessment should not affect the performance of subsequent tests. This is in an effort to enable optimal performance in each assessment and allows for valid comparisons with previous testing results (McGuigan, 2016a). A suggested approach is to administer tests in this order (Fukuda., 2019; McGuigan, 2016a):

1. Non fatiguing tests (e.g., height, weight, flexibility, skinfold and girth measurements, vertical jump)
2. Agility tests (e.g., T-test, pro agility test)
3. Maximum power followed by strength tests (e.g., vertical jump, standing long jump, 1RM power clean, 1RM squat, isometric mid-thigh pull)
4. Sprint tests (e.g., 40 m sprint with split times at 10 m and 20 m)
5. Local muscular endurance tests (e.g., push-up test)
6. Fatiguing anaerobic capacity tests (e.g., 300-yard [275 m] shuttle)
7. Aerobic capacity tests (e.g., 1.5-mile [2.4 km] run or Yo-Yo intermittent recovery test)

An effort should be made to administer fatiguing anaerobic capacity tests and aerobic tests on a different day than the other assessments. However, if this is not feasible and these tests must be performed on the same day, then they should be performed last, after an extended rest period (McGuigan, 2016a). Additionally, in the 2-3 days leading up to testing, the heavy training days should be limited so the athletes will have less residual fatigue present when testing. This is especially true of performance tests of vertical jump, maximal strength, aerobic, and anaerobic work (Fleck, S. J., & Kraemer., 2014). This is somewhat an area of controversy, if you allow too much rest then you may lose ecological validity. Finally, when administering a battery of tests, each test should be separated by at least 5 minutes to prevent the effects of fatigue from confounding test results (Cormack & Coutts., 2021a; McGuigan, 2016a).

The date, time, and purpose of a test battery should be announced in advance to allow athletes to prepare physically and mentally (McGuigan, 2016a). If new participants are involved, a brief supervised pretest practice or familiarization session should be held one to three days before the test. This is an opportunity for the athletes to exert themselves at a sub-maximal intensity; while also becoming familiar with the physical demands for each test. Familiarization should take place in a setting as similar to the testing environment as possible so unforeseen issues may be identified prior to data collection (Fukuda., 2019). Instructions should cover the purpose of the test, how it is to be performed, the amount of warm-up recommended, the number of practice attempts allowed, the number of trials, test scoring, criteria for disallowing attempts, and recommendations for maximizing performance. The instructions given to the athletes need to be clear and concise, since this will increase the reliability and objectivity of the test (Morrow., 2011).

Finally, athletes should receive encouragement during maximal efforts as they perform their assessments to help motivate them. This is so practitioners may have more accurate results from the athlete’s current ability to perform. Positive feedback should be provided by the assessment staff with the intention of maintaining a high level of engagement and motivation of the athletes (Fukuda., 2019). Having a coach present when possible will also likely help motivate athletes to perform their best during the assessments.

Additional Considerations

Possible factors that may influence the outcomes of the tests should be considered as well. This can include sex, which can affect the validity and reliability of a test (McGuigan, 2016a). The environmental conditions should not differ from test to test. For any particular test conducted on the ground, the surface should always be the same and should not be wet for one test and dry for another. Maximum strength tests should use the same type of racks with the supports set at the same height for a given athlete. For jumping tests, the type of equipment used should be consistent. Athletes should wear the same type of gear for each repeated test.

The reliability of testing improves with pretest warm-up (Baumgartner & Jackson., 1998). An appropriately organized warm-up consists of a general warm-up followed by a specific warm-up. The specific warm-up can often be performed leading into the test and serve as a method for refamiliarizing the athlete with the cues and expectations. Both types of warm-ups include body movements similar to those involved in the test.

Potential Assessment Methods to Consider

While there is a range of assessments that may be carried out using a structured approach to obtaining data from an athlete emphasis should be placed on timelier and performance-based approaches. More clinical/research approaches for assessing hydration (stable isotope dilution, neutron activation analysis, serum sodium concentration, etc.) or body composition (hydrostatic weighing, CT scan, doubly labeled water, ultrasonography, etc.) will be excluded from this review due to the high cost, skill of the administration, and time requirements they take to effectively get implemented within a testing protocol.

When evaluating the equipment for conducting assessments, products should first be evaluated under the prism of competitiveness. This model is broken down into first determining the functionality of an assessment tool, then choosing a method that is reliable before finally settling on equipment that is convenient to use while falling in the price range of the team/organization (Christensen., 1997). The technologies below are accompanied by a table at the end of each assessment group (i.e., hydration, body composition, vertical jump height, and maximal strength) with information related to the variable(s) each tool contains, their limitations, its precision/reliability, cost, invasiveness (when applicable), administrator skill required, the time required, and where it has application the lab vs the field.

Hydration Tests

An appropriate status of hydration holds many benefits to daily living. It is essential to life and plays an important role in metabolism, nutrient transportation, circulation, and temperature regulation (Horswill & Janas., 2011). These outcomes are vital to achieving optimal performance while reinforcing the need to be well-hydrated in preparation for, during, and after training/competition. Hydration is a means of estimating the body's water content and is an important factor to consider when developing testing procedures.

Acute dehydration is associated with the impaired ability to train/compete (particularly in endurance events) (Kraft et al., 2010), greater fatigue (short and long-term), decreased maximum strength (Hayes & Morse., 2010; Judelson et al., 2007; Kraemer et al., 2001; Schoffstall et al., 2001), poor cognitive function (Wilson & Morley., 2003), reduced motor skills (Devlin et al., 2001; Zubac et al., 2020), increased risk of injury (Hammer et al., 2023), and increased potential for heat illness (Rodrigues et al., 2014; Shirreffs et al., 2004). While chronic dehydration may impair cognitive function and mental performance (Adan., 2012; Grandjean., 2007; Wilson & Morley., 2003), impaired ability to train/compete (Kraemer et al., 2001; Shirreffs et al., 2004; Walsh et al., 1994), and impaired motor control (Devlin et al., 2001).

The inclusion of practical hydration testing in a performance setting should be completed early during testing. The results from this type of assessment can impact tests conducted later in the session. When selecting hydration methods, it is important to determine whether the goal is to conduct a single assessment of hydration status or assess changes over time. Typically, one assessment is conducted with a couple measures to determine reliability when additional tests follow the hydration assessment. The utilization of a single assessment should apply the appropriate gross test (i.e. bioimpedance and sensation of thirst) and interpret cut-offs from bodily fluids with caution, especially in the case of urinary markers (Cheuvront et al., 2015). Examples of cut-offs include plasma osmolality lower than 296 mmol/kg, U_{OSM} below 700 mmol/kg and USG under 1.020 (Fortes et al., 2011, Sollanek et al., 2011, Cheuvront et al., 2013). With the use of repeated measures, adequate controls should be present when possible. These considerations include the potential influence of substrate utilization and metabolic water production on body mass when participants are engaging in exercise (Barley et al., 2020).

The current gold standard for assessing hydration is considered to be plasma osmolality (P_{OSM}). P_{OSM} is a well-rounded test in regard to the time required to administer and reliability (Cheuvront & Kenefick., 2011 Sollanek et al., 2011). This assessment does require adequate tester skill, costs to cover testing, is invasive, and is debated to be the gold standard (Armstrong., 2007; Armstrong et al., 2013; Cheuvront et al., 2013). This makes the use of P_{OSM} more practical in a lab setting rather than in the field. When assessing P_{OSM}, considerations that should be present include:

- The sensitivity of P_{OSM} to detect mild hypohydration (< 3%) has been debated (Carlock et al., 2004; Cheuvront et al., 2013; Hamouti et al., 2013)
- After exercise half of all plasma volume lost recovers within one hour even without any fluid ingestion (Nose et al., 1998) (possibly resulting in incorrectly concluding a greater magnitude of dehydration)

- P_{OSM} is influenced by food as body water shifts from the vasculature into the gut (Gill et al., 1985)
- P_{OSM} is highly individual and should be compared to baseline measures as opposed to well-known norms (Cheuvront & Kenefick., 2011; Cheuvront et al., 2013)
- There is a strong physiological basis for inferring the relationship between P_{OSM} and intracellular hydration (meaning it is still not a direct measure) (Cheuvront & Kenefick., 2011; Cheuvront et al., 2013).

Urine variables are a common way to assess hydration status since it compares water and other substances that increase in concentration as the volume of water decreases (Zubac et al., 2018). Urinary hydration assessment methods include urine specific gravity (USG), urine osmolality (U_{OSM}), urine color (U_{COL}) and urine volume (Fernández-Elías et al., 2014). USG is assessed by placing a small volume of urine (~20ml) onto a refractometer and the urine density is then compared to double distilled water (density = 1.000) that is used to calibrate the equipment in advance. A result greater than 1.020 is typically considered hypohydrated (Zubac et al., 2016; Fernández-Elías et al., 2014). U_{OSM} assesses the total solute content of the urine and involves collecting ~20 μL of urine and assessing its freezing point depression, with dehydration indicated when osmolality is over 700 mmol/kg (Fernández-Elías et al., 2014; Sawka et al., 2007). An alternate way to assess U_{OSM} is with a hand-held conductivity meter, which uses an estimation from USG (Shirreffs & Maughan., 1998). U_{COL} is a subjective evaluation of the pigmentation of a urine sample (urochrome is what creates the color in urine) and uses a Likert scale. However, ingesting vitamins, nutritional supplements, or prescription drugs are substances that alter urine color, amount, or composition, potentially making this an invalid method (Armstrong et al., 1994). Considerations when implementing a urinary assessment for hydration status include:

1. A urine sample reflects all urine in the bladder since the previous void, so the time elapsed since the last void will influence results (Popowski et al., 2001)
2. Ingesting fluids with little sodium (hypotonic) results in water getting excreted before the intracellular and extracellular fluids equilibrate, this can cause errors in the urine results indicating euhydration (Armstrong et al., 1998; Armstrong et al., 2007)

3. Urine variables poorly correlate to more robust measures when assessing acute hydration status due to hormonal changes during rehydration and the influence this has on the reabsorption of water and electrolytes (Oppliger et al., 2005; Popowski et al., 2001)
4. Research reports accuracy of urinary assessments ranging from being robust to in adequate (Armstrong et al., 1998; Francesconi et al., 1987; Zubac et al., 2019)
5. Individuals will have biological variation between them, making the use of a single cut-off point an opportunity for errors to be present (Cheuvront et al., 2013). Comparisons should be made with baseline measures when possible.
6. Suggested the use of a single measure from a sample is excluded due to the large degree of potential confounding factors and questionable normative values (Cheuvront et al., 2015)
7. Urinary excretion rate has identified as a potential confounder of concentration-based assessments which should be accounted for where possible (Barley et al., 2020)
8. Urinary measures represent the renal response to fluid homeostasis and not real-time hydration status at a cellular level (Hew-Butler & Weisz., 2016)

Overall, the convenience of urinary measures allows for their use in both the laboratory and field-base setting (Barley et al., 2020). It has been suggested that baseline measures should be created to better account for unique variations for an individual rather than assigned a cut-off limit for all (Cheuvront et al., 2015). Additionally, when rapid rehydration occurs, approaches apart from urinary measures should be used due to a higher likelihood of invalid results (Barley et al., 2019; Zubac et al., 2019).

Obtaining blood variables is another way to determine hydration status in addition to erythrocytes (red blood cells), white blood cells, platelets, and plasma (Cheuvront & Kenefick., 2011). Additionally, containing some of these other blood markers may be useful for additional testing to determine other status factors for the athlete. Most hydration tests involving blood are collected using either venipuncture or a finger-prick lancet, with the venipuncture approach providing samples to assess blood composition, plasma solutes, and hormone concentration (Oppliger & Bartok., 2002). This approach to determining hydration status is typically more invasive, expensive, and time-consuming, with an additional minor risk of infection or vein damage. Additionally, the practical limitations of this assessment method can influence the collection and real-time analysis of blood in field-based settings, which is why this test is often limited to a lab (Barley et al., 2020). Hematocrit changes, using finger stick, will occur when dehydration reduces the plasma volume, increasing the concentration of red blood cells (Oppliger & Bartok., 2002). While this type of assessment does not require a phlebotomist, the equipment required for analysis does typically come at a substantial cost (Armstrong., 2007; Oppliger & Bartok., 2002). Consideration when implementing a hematocrit assessment for hydration test includes:

- Posture, arm position, skin temperature, tourniquet usage and several other factors can all influence reliability (Kavouras., 2002; Sawka & Coyle., 1999)
- Hematocrit change from dehydration is less in heat-acclimatized athletes (Sawka & Coyle., 1999)
- Exercise can alter plasma volume for up to 72 h (Robertson et al., 1988)
- Hematocrit concentration vary both between- and within subjects, meaning that results should be considered relative to the athlete so reliable baseline measurements may be obtained (Cheuvront & Kenefick., 2011; Kavouras., 2002; Shirreffs., 2000)
- Hematocrit is not a direct assessment of cellular hydration but instead an assessment of plasma volume, making it an inference rather than a direct measure (Barley et al., 2020; Kavouras., 2002).

While hormonal variables are an option for assessing hydration, it is not practical due to administrator skill, cost, and invasiveness as well as poor reliability (Barley et al., 2020). Other approaches to evaluating hydration status besides relying on examining different fluids include with body mass, vital signs, and sensations of thirst, bioimpedance, and dual-energy X-ray absorptiometry (Armstong., 2007). One of the major limitations of these approaches is that hydration status will likely be unable to determine fluid shifts within the body (Barley et al., 2020), that is how the fluid is distributed within the cells or vascular to the interstitial compartments.

Body mass is a cost-effective and simple approach to hydration assessment since it can be used to estimate the volume of water lost during exercise and/or thermal exposure. It is important to consider fluid and food intake and excretion via urine and feces around the time of the measurement (Shirreffs., 2020). The use of floor scales is the most practical way to determine mass differences in participants so long as the model and method of measurement used have strong reliability and accuracy (Cheuvront & Kenefick., 2017; Gerner., 2006; Owen et al., 2019). Additionally, body mass assessments may be confounded by time of day, food/fluid consumption, sweat composition, respiratory water loss, exercise-induced substrate utilization, and metabolic water production (Cheuvront & Kenefick., 2017; Hew-Butler et al., 2016; Maughan et al., 2007; Shirreffs., 2020). To better determine changes in body mass, Cheuvront and Kenefick (2017) developed an equation to account for the potential cofounders:

$$\begin{aligned}\Delta BM = {} & (H_2O_{drink} + H_2O_{food}) \\ & - (H_2O_{urine} + H_2O_{feces} + H_2O_{skin} + H2O_{resp}) \\ & + (solids_{in}) - solids_{out}) + (gases_{in} - gases_{out})\end{aligned}$$

When accounting for these factors, changes in body mass can provide an indication of whole-body hydration for up to 2 weeks, assuming a relatively consistent energy balance and that the participant is not growing as a result of youth maturation (Cheuvront et al., 2004; Leiper et al., 2001). Typically, this method is used before and after training when food intake is not a problem.

Bioelectrical impedance (BIA) is a quick approach for assessing hydration and involves a low alternating current being directed through the body and the resistance to the current is measured to estimate total body water (TBW) (De Lorenzo et al., 1997). Considerations when using this assessment approach includes participant posture, skin temperature, electrolyte balance, ingestion of food, intense physical activity, alcohol ingestion, and protein malnutrition (Kavouras., 2002; Mialich et al., 2014). The typical error found for TBW assessment ranges from 1.5–2.5 kg for BIA analysis, while more advanced BIA spectroscopy is more accurate and can predict extracellular and intracellular water (Oppliger et al., 2002).

Sensation of thirst is a subjective method of determining hydration status. A Likert scale ranging from 1 (not thirsty at all) to 9 (very, very thirsty) has been used to determine hydration status, with an athlete being considered hypohydrated if their rating is between a 3 and 5 (Armstrong et al., 2014; Young et al., 1987). Limitations for the perception of thirst include factors such as palatability, time allowed for fluid consumption, gastric distention, age, gender, and heat acclimation status (Greenleaf & Morimoto., 1996; Hubbard., 1990; Ormerod et al., 2003). To evade being deemed dehydrated, athletes may intentionally provide an inaccurate response to this assessment. Barley and colleagues (2020) suggest that this assessment, along with vital signs get used alongside another more robust test to provide more context.

Overall, without access to advanced laboratory equipment, urine specific gravity is one of the best options for determining hydration status. However, limitations should be regularly considered. It was also suggested by Barley and colleagues (2020) that the use of multiple measures of hydration status are used since:

- No single measure of hydration is without limitations, nor does it provide a comprehensive measure
- Multiple assessments reduce the likelihood of incorrect categorization of hydration (i.e. hypo, hyper or dehydrated) due to measurement error
- Different methods of hydration assessment evaluate fluid in different parts of the body, providing a more comprehensive picture of where fluid is retained

Limitations of each method should be considered when using them in a multi-faceted approach. In cases when logistical issues arise, it is important to try to work within such limitations to select the best testing battery possible for hydration status and then interpret the results through a critical lens (Table 4.1).

Table 4.1.

Characteristics of Methods for Assessing Hydration

Assessment	Variable(s)	Limitations	Precision/ Reliability	Cost	Invasiveness	Administrator skill required	Time required	Lab vs Field
Haematocrit	Plasma volume	Assessment of plasma volume (not cellular hydration), making it an inference rather than a direct measure. Results should be considered relative to the athlete so reliable baseline measurement. Exercise can alter plasma volume for up to 72 hours.	3	Centrifuge: $30 - 500 per participant (excluding cost of test tubes)	3	3	<30:00	Lab
Plasma Osmolality	mmol/kg	Highly individual and should be compared to baseline measures as opposed to well-known norms. Not a direct measure.	4	Centrifuge: $30 - 500 Osmometer: $250-1500	4	4	<30:00	Lab
Urine Specific Gravity	Urine Density (mmol/kg)	Ingesting fluids with little sodium results in water getting excreted before the intracellular and extracellular fluids equilibrate, this can cause errors in the urine results indicating euhydration. Biological variation between individuals makes the use of a single cut-off point an opportunity for more errors to be present.	2	$280-670	2	2	<1:00	Both
Urine Osmolality	mmol/kg	Many confounding factors.	2	Osmometer: $250-1500	2	3	<30:00	Both
Urine Color	Pigmentation	Ingesting vitamins, nutritional supplements, or prescription drugs are substances that have been reported to alter urine color, amount, or composition	1	Free (excluding cost of cups)	2	1	<1:00	Both
Body Mass	Kg	Time of day, food/fluid consumption, sweat composition, respiratory water loss, exercise-induced substrate utilization and metabolic water production will cause variation	4	$30-100 price of digital scale	1	1	<1:00	Both
Bioelectrical Impedance	TBW, extracellular and intracellular water	Participant posture, skin temperature, electrolyte balance, ingestion of food, intense physical activity, alcohol ingestion, protein malnutrition, error for TBW assessment ranges 1.5–2.5 kg	3	$83 -9,140	1	1	1:00-3:00	Lab

Body Composition Tests

Body mass and composition are variables that can be specific to the performance outcomes for individual sports and for the specific positions an athlete may play in a team sport setting. Both variables can influence strength, speed, power, change of direction (CoD), and endurance capabilities (Leedy et al., 1965; Lukaski & Raymond-Pope., 2021;). Typically, lower fat content (a greater muscle-to-fat ratio) can be advantageous in sports where speed is involved (Leedy et al., 1965; Lukaski & Raymond-Pope., 2021; Silvestre et al., 2006). More body mass is advantageous for positions where larger total size is necessary (e.g., sumo wrestling or a defensive lineman). Additionally, estimating measurements of body size, composition, and distribution of fat and lean body mass (LBM) are important for practitioners to track for the following reasons:

- Determine the risk for health problems (i.e., metabolic syndrome, diabetes, etc.)
- Functions as a determinate for "fitness" in sport
- Useful in monitoring weight loss or weight gain consequences for sport or health (allows goal setting)

The following are metrics help to determine characteristics that make up for one's body composition (Bredella., 2016; Ethun., 2016):

- <u>Body mass</u> (kg) is the amount of substance in a person's volume
- <u>Body composition</u> = Fat free mass (FFM) and Fat Mass (FM)
- <u>Fat</u> is composed of adipose tissue and lipids
- <u>Essential Fat</u> is the fat needed to maintain normal physiological functions (found in such tissues as muscles, nerve cells, bone marrow, intestines, heart, liver, and lungs).
    - percentage of total body fat mass that is necessary for insulation, protecting our vital organs, vitamin storage, and building key cell components such as steroids, and hormones necessary for effective cell communication
    - constitutes about 3-7% of the total weight in men and about 5-12% in women (Bredella., 2017; Ethun., 2016)

- Storage Fat is fat accumulated in adipose tissue – includes visceral fat (protective fat around organs) and subcutaneous fat
- LBM = FFM + essential fat
- FFM = mass with no fat included

Different compartment models are used to distinguish how assessment tools determine body composition based on the multiple characteristics that make up body fat. The models of body composition are as follows, with the higher models often proving to be more accurate (Kuriyan., 2018):

- Single-compartment model- this is simply your body's mass
- Two-compartment (2C) model- which is considered the simplest approach since it divides FM by FFM to provide a value
- Three-compartment (3C) model- takes FFM and distinguishes it as lean tissue mass (LTM) and bone mineral content (BMC). Further, FFM is divided into water (total body water [TBW]) and the remaining solids (protein and minerals, fat-free dry mass [FFDM])
- Four-compartment (4C) model- divides body mass into fat, mineral, TBM, and protein (which is counted as a residual), this model, however, is not practical in the applied setting
- Multicompartment models- this divides the body down further into divides the body into water, nitrogen, calcium, potassium, sodium, and chloride (Heyward & Wagner., 2004). Much like the 4C model, this approach is very impractical in the applied setting.

Indirect methods of assessing body composition are used to estimate fat content and can fall into property-based or component-based categories. Property-based methods measure specific items such as body volume, decay rates of specific isotopes, or bioelectrical resistance. The component-based method depends upon well-established models that represent ratios of measurable quantities of body components that are assumed to be constant both within and between individuals. This is accomplished by using the estimates of a property method for an approximation of a specific component. Some important questions to ask when selecting a body composition assessment method (Duren et al., 2008):

- Why are you measuring body composition (e.g., research, monitoring athletes, monitoring patients, etc.) – trade-off between accuracy and speed?
- How large is the group being measured?
- What equipment is available?

Field methods for assessing body composition include anthropometry, BMI, waist circumference, waist-hip ratio, skinfold measurement, and BIA (Kuriyan., 2018). Laboratory methods include: hydrodensitometry, air displacement plethysmography, isotope dilution method, dual energy x-ray absorptiometry (DEXA), computed tomography (CT) and computed tomography body composition (CTBC), magnetic resonance imaging, and whole-body potassium counter and BIA (Kuriyan., 2018). Of these tools DEXA, has the highest validity, while air displacement is the most practical in a performance setting.

DEXA (3C model) is based on the relationship between whole body density (BD) and the respective densities of the body compartments. This assessment is considered the current gold standard for body composition assessment in a non-clinical setting. DEXA can estimate fat mass, lean body mass, and bone mass. This is accomplished by using a source that generates X-rays at two energies. The differential attenuation of the two energies is used to estimate the bone mineral content and the soft tissue composition (Bone Density Scan., 2015). These measurements are based on the assumption that the hydration of fat-free mass remains constant at 73%, however, it may vary from 67%–85% (Rodriguez-Sanchez & Galloway., 2015). DEXA takes about 10 minutes to complete per athlete (Bone Density Scan., 2015; Clasey et al., 1997; Lang et al., 2015). The practicality of this assessment is limited to the laboratory setting.

BIA (2C model) is based on the relationship between the volume of the conductor (in this case, the human body), the conductor's length (height or length of the limbs), the components of the conductor (i.e., fat and fat-free mass), and its impedance. The estimates of body composition are based on the assumption that the overall conductivity of the human body is closely related to lean tissue. This is attributed to lean tissue holding water that better conducts the electrical currents passing through the region. The impedance value is combined with anthropomorphic data to give body compartment measures. The technique involves attaching surface electrodes to various locations on the arm and foot. Alternatively, the patient can stand on pad electrodes. Accuracy of BIA is approximately ±2-3% and is dependent upon the following variables (Demura & Sato., 2015):

- Abstain from eating and drinking within 4 hours of the test
- Avoid exercising within 12 hours of the test
- Void (urinate) completely prior to testing
- Do not drink alcohol within 48 hours of the test
- Avoid taking diuretics prior to testing unless instructed by your physician

BIA is a method that has realized technological advancements recently that makes it a fast, accurate and reliable method to assess body composition depending on the selected tool. The SECA (mBCA 515 v1.1 Hamburg, Germany) for example, has a very strong test–retest reliability for all variables with an interclass correlation coefficient (ICC) = 0.98 to 0.99 and coefficient of variation (CV) = 1.76 to 3.41% (Bosy-Westphal et al., 2013, 2017; Jensen et al., 2019; Peine et al., 2013). A consideration for BIA testing is with women and their menstrual cycle, which causes more frequent and greater alterations in hydration compared to men (Cumberledge et al., 2018). The use of BIA for testing is frequently limited to the laboratory setting for the more valid assessment, with lower validity assessment being able to take place in the field.

Anthropometry is the study of human body dimensions (limb lengths and circumferences), including body volumes, masses of body segments, centers of mass, and internal properties (content of fat, muscle, bone, etc.). Anthropomorphic techniques are often used to estimate body composition which involve skin-fold and limb circumference measures. Due to its ease of use, skin-fold thickness measurements are one of the most commonly used techniques.

Skinfold thickness (2C-4C models) is an efficient (relatively fast) measurement conducted with some initial training for a tester. It involves measuring the subcutaneous fat thickness at specific sites using a skinfold caliper and a non-stretchable measuring tape to correctly locate the measurement area. The technique is based on the assumption that the subcutaneous adipose layer reflects total body fat, but this association may vary with age and sex. There are multiple models for skinfold measurements ranging from as few as two sites up to nine (Simple measures – skinfolds. DAPA Measurement Toolkit). When compared to underwater weighing (the previous gold standard), skinfolds are correlated at r=0.90 and r=0.89 for seven site and three site measurements, respectively (Duren et al., 2008). It is the tester's choice to select a number of sites to measure, impacting how valid they want the results from this test. Skinfold tests, when performed correctly, have about a ± 3% error. This approach to body composition assessment is inexpensive (~$16-$500), non-invasive, requires little space and is portable (good for both field and lab tests). Use of a standardized protocol increases the reliability of skinfold thickness measurement (same measurement order at the same locations, typically the right side of the body), intra-observer and inter-observer errors are low compared to between-individual variability and is a convenient and cost-effective means of monitoring changes in body composition of large groups over time (Simple measures – skinfolds. DAPA Measurement Toolkit). A measuring tape and markers should be utilized to determine the measurement sites.

While hydrostatic weighing (2C model) was considered a gold standard, its practicality in the performance testing setting is limited due to equipment costs, administrator skill, and long testing time (Hydrostatic underwater weighing; DAPA Measurement Toolkit). A similar example of displacement is with plethysmography (2C model) that evaluates based on the amount of air displaced from a chamber the athlete occupies (Ackland et al., 2012). One example of this is the BodPod. This tool has a validity of r=0.93 when compared to the previous gold standard, hydrostatic weighing (McCroy et al., 1995).

Height and weight charts, BMI, and waist-to-hip ratio, while commonly used methods; are limited to practical use in non-athletic populations. Limits include (Duren et al., 2008):

- No real measure of body composition or tissue distribution
- Does not account for differences in body framework
- Does not account for training background

Additionally, while BMI is a method, it uses estimates to determine the degree of being overweight.

Finally, body composition analysis has advanced so that it is now becoming more feasible to use mobile technologies that aid making data more easily obtained in the field rather than in specialized laboratories (Villa et al., 2016). Additionally, new advances in traditional anthropometry approaches are occurring with the development of automated optical scanning systems that can provide body dimensions such as length, width, and circumference (Bourgeois et al., 2017). BIA instruments based on smartphone technology are also becoming more readily available and transportable (Choi et al., 2015; Heymsfield et al., 2015), however, these methods are subject to high error. As innovations in sensor-based technologies continue to improve, effective evaluation of body composition with these techniques will be more frequently used (Kuriyan., 2018). Information provided in Table 4.2 provides details on the previously mentioned body composition assessments so the best testing modality may be selected.

Table 4.2.

Characteristics of Methods for Assessing Body Composition

Assessment	Variable(s)	Limitations	Precision/ Reliability	Cost	Invasiveness	Administrator skill required	Time required	Lab vs Field
Densitometry DEXA	3C (fat mass, lean body mass, and bone mass)	Measurement can be affected by the size of the patient, assumes a constant hydration of lean soft tissue, repeatability (CV) in the range of 1-2 per cent BF and 0.5-2 per cent for LT	4 to 5	$50-185 per scan	2 to 3	5	<10:00	Lab
Skinfold	2C (subcutaneous fat, by estimating body density to derive per cent body fat)	Time of the assessment and ± 3% error indirectly assesses compartments. technician skill, type of calipers and the prediction equation used	3 to 4	$11-370	2	3 to 4	3:00-12:00	Both
Displacement (Plethysmography) (BodPod)	2C (total body fat and lean tissue)	Less valid with young children and Indian populations	3 to 4	$1,900-19,200 or $130 per test	1	4 to 5	5:00-8:00	Lab
Bioelectrical Impedance	2C (Impedance value of the human body's lean tissue combined with anthropomorphic data to give body compartment measures)	Accuracy of BIA is approximately ±2-3%. Dependent upon eating and drinking within 4 hours of the test, avoid exercising within 12 hours of the test, void (urinate) completely prior to testing, do not drink alcohol within 48 hours of the test, avoid taking diuretics prior to testing unless instructed by your physician. Women and their menstrual cycle, which causes more frequent and greater alterations in hydration compared to men	3 to 4	$80-28,300	1	2 to 3	1:00-5:00	Both
BMI	kg/m^2	Poor assessment tool for athletes since: not a real measure of body composition nor tissue distribution, does not account for differences in body framework, does not account for training background.	1	Free	1	1	1:00-2:00	Both
Ultrasonography	Cross Sectional Area, Pennation angle, tissue thickness (cm^2)	Muscle thickness, muscle cross sectional area, pennation angle	5	$8,500-22,200	3	4 to 5	5:00-20:00	Lab

Vertical Jump Tests

Vertical jump testing (VJT) is a common assessment used in determining lower limb muscle strength and power because it is relatively simple to administer, while also being an important functional parameter in most sports (Bosco et al., 1983, Kraska et al., 2009). VJT is strongly correlated with other performance measures: sprints, CoD, agility, lower body maximum strength measures, various sport specific tests (Aouadi., 2012; Carlock et al., 2004; Kraska et al., 2009; Pupo et al., 2020). If there are no constraints around the quantity of examiners, the VJT can be a quick and effective approach to estimating of the athlete's lower body explosive capabilities (Barker et al., 2018; Ronnstand et al., 2008). Common metrics that are tracked in VJT include JH, peak force (PF), impulse, peak power (PP), and rate of force development (RFD). Changes to these variables can provide insight into the effectiveness of aspects of training programs including strength and conditioning (Kawamori et al., 2006).

Different types of jumps are a means of assessing specific aspects of the athlete. A static/squat jump (SJ) can be used to measure concentric force production, while a countermovement jump (CMJ) measures coupled eccentric-concentric force production (indicating stretch-shortening cycle [SSC] function or "reactive strength") (Jakobsen et al., 2012; Suchomel et al., 2018). After obtaining both CMJ and SJ data the eccentric utilization ratio (CMJ / SJ) or the Pre-Stretch Augmentation ($[((CMJ\text{-}SJ) \times SJ^{-1}) \times 100]$) can determine the athlete's current use of the SSC (McGuigan et al., 2006; Young et al., 1999). Additionally, unloaded and loaded conditions can derive additional context about the athletes. The weighted condition, when compared against unweighted trials, provides insight into the fall-off due to an external load. The smaller the fall-off, the stronger the athlete typically is (Kraska et al., 2009; Stone et al., 2003). Additionally, weighted jumps potentially detect fatigue better than unweighted jumps (Hornsby et al. 2017). Jump testing is standardized by either having the participant place their hands on their hips or have a PVC pipe on their shoulders to eliminate the use of their arms. This will help to eliminate the technical component of the arm swing, which may vary substantially between participants, positions, and especially sports (Hara et al., 2006; Hara et al., 2008). Vertical jump with step(s) is an additional test that can relate to the specificity of a sport (i.e., basketball or volleyball).

When determining the test to administer, there are multiple approaches to acquiring VJT data. Depending on the approach for testing, there may be a flight time (FT) equation that is applied to the data. This equation aids in predicting the height achieved during the jump. Vertical jump height can be calculated with three different methods (Aragón., 2000 ; Linthorne., 2001; Moir., 2008):

- Time in the air (TIA): jump height (JH) = ½ g $(t/2)^2$
    - g=gravity acceleration (i.e., 9.81 m/s^2)
    - t=TIA
- Vertical velocity of the center of mass (COM) at take-off (TOV): flight=$\frac{v_{to}^2}{2g}$ (this is often used for calculating the height with force plates)
    - v_{to}=vertical takeoff velocity
    - g=gravity acceleration
- Adding displacement of the COM prior to take-off of the height calculated using TOV (TOV+s)
    - Occurs with a motion analysis system to calculate the vertical displacement of the COM prior to take-off and is paired with a force platform to calculate TOV
    - The jump heights with this method are greater than those calculated using both TIA and TOV.
    - Error from this method may relate to the inability to synchronize the force platform and video signals

The equation used commonly to convert contact mats, photocell mats (PCMs), accelerometers, or other complex and expensive devices such as high-speed video systems is h=$\frac{T_f^2 \cdot g}{8}$ where g=gravity acceleration and Tf = Flight Time (García-López et al., 2013). However, this calculation provides a determination of the rise of the body's COM achieved during the jump, not the achieved height (Whitmer et al., 2015). When both the force plate and photocell/contact mat detect the same FT, both equations will produce the same JH. The equation used to determine JH can vary between equipment that is used for collection since approaches to obtain JH data can include contact mats, linear position transducers, PCM, accelerometers, force plates, or other complex devices such as high-speed video systems (Attia et al., 2017; Cronin et al., 2004; García-López et al., 2013; Glatthorn et al., 2011). These devices can range in price, validity, and transportability for collecting data in the lab setting or on the field. Additional methods that do not require FT; but rather a physical marker of the height achieved includes Vertec or chalk on the fingertips near a wall.

The current gold standard for determining vertical jump height is with force plates (Cronin et al., 2004; Menzel et al., 2010; Nigg & Herzog., 1994). Force plates can provide JH, PF, and RFD metrics all at once while collecting data with a higher sampling rate and better ability to assess the time at which take-off occurs (Nigg & Herzog., 1994). To obtain valid data with this assessment tool, Hori and colleagues (2009) suggest that practitioners use a force platform with the highest possible sampling frequency but in considering acceptable reliability (less than 2% difference from the reference values in all measurements and nearly perfect correlation) considering the use of sampling frequencies as low as 200 Hz have been suggested. The lower frequency will also help reduce disk storage space when the transfer of sample data takes place. Practitioners should keep sampling frequency consistent at all testing occasions, no matter which sampling frequency is selected, to allow valid comparison of performance variables across time (Hori et al., 2009). Additionally, if a dual force plate set-up is used, then asymmetries between the tested limbs can then be determined. Force plates can range in price from as low as $500 per unit up to ~$50,000 (PASPORT Force Platform, PASCO PS-2141; Merrigan et al., 2021). The transportability of force plates is improving; however, their use is still most practical in a lab-based setting due to being very sensitive to extraneous vibrations and need to be mounted as specified by the manufacturers to preserve the integrity of the signal (Cronin et al., 2004).

Linear position transducers (LPT) are a validated method to obtain objective measures of JH since they indirectly measure displacement (Cronin et al., 2004). The device works by securing the ends of the LPT to a bar or PVC pipe on the athlete's shoulders or their waist and having the athlete perform their jump (Cormie et al., 2007; Cronin et al., 2004). As the athlete moves the bar, the length of the LPT cable will change altering the voltage n the potentiometer (variable resistor) , displacement is determined by producing a continuously variable voltage output signal proportional to the physical position of the bar. The best approach to obtaining a valid result with this method is having 4 total LPTs, with two situated on opposing ends of the bar (Cormie et al., 2007). The LPT's are suspended from a relatively large structural rectangle above (or below) the athlete, thus, forming a triangle between bar and the LPT's. This allows for triangulation of the displacement as long as the distance between the two LPTs on both sides is known and remains constant. This accounts for both vertical and horizontal displacement (which most athletes will have some forward or backward deviation when performing their jumps). Metrics that can be obtained from LPTs include duration of contraction, mean and peak velocity, peak acceleration, mean and peak force, mean and peak power, instantaneous power, force at 30 and 100 milliseconds, total impulse, and total work done (Cronin et al., 2004). This assessment can be used practically in both a field and lab setting (Cronin et al., 2004). LPTs can cost anywhere from ~$570-3,000 per unit. Set up of an LPT system can range from use in the laboratory to a field-based setting in better control of movements can occur or in the field.

Accelerometers measure changes in acceleration. From acceleration measures, calculation can obtain JH, vertical force (Fv), power (P), leg stiffness (kleg), and reactivity index (RI) data (Choukou et al., 2014). Recently, the use of accelerometry has become increasingly favored especially for field testing. Accelerometers should be placed closer to an athlete's COM to gain more accurate data regarding vertical displacement (Cabarkapa et al., 2021; Requena et al., 2012). Locating an accelerometer distally on the limbs creates more error due to extraneous movement of the limb. This tool has been validated against LTPs, FPs, and high-speed video systems (Cabarkapa et al., 2021; Requena et al., 2012). However, Cabarkapa and colleagues (2021) found that, when compared against FPs, accelerometry often overestimates JH. Choukou and colleagues (2014) also reported invalid JH, velocity, and power with accelerometers when compared to FPs. These issues can be resolved by developing a correction equation for the equipment (Cabarkapa et al., 2021). Finally, this assessment tool can be used in the laboratory and field-based settings, making it a portable and cost-effective alternative to FPs (Cabarkapa et al., 2021; Requena et al., 2012). Accelerometers range in cost from $40-~20,000.

High-speed video systems (HSVS) can be used to determine JH in two ways 1) knowing the frame rate and determining the number of frames collected while the participant is in the air and use the lapsed time to determine vertical displacement. 2) Using a multiplier to determine and known distance and using this to determine the displacement. HSVS are a cheaper alternative compared to force plates and some models (i.e., Kinovea) are easy to use with little training necessary to run the equipment (Balsalobre-Fernández et al., 2014).To a point, the higher the sampling rate the better, recent evidence suggest that flight time error steadily decreased form 120 hz to 240 hz, with little difference at higher rates (Pueo et al. 2023). Similar to other methods (higher sampling rates are best), the conditions of the surroundings are also important to consider. Factors related to lighting, consistent and adequate distance of filming, and having a reference item in frame are often necessary to obtain optimal results (Balsalobre-Fernández et al., 2014; Pueo., 2016). However, with the advances in the applications and hardware of many mobile phones, the ability to capture vertical jumps with smartphones is becoming more feasible. While most current smartphones can record video at framerates of ~60 fps/hz (or one image every 16.7 ms), the goal is to aim for at least 200 fps to obtain a more accurate JH (Pueo., 2016; Pueo et al., 2020). Higher frame rate is beneficial since they provide more detail of a movement frame-by-frame replay as the jump from one frame to another is smaller and the exposure time must also be faster to help reduce blur from motion (Melville., 2017). With higher frame rates, the faster shutter speeds accompanying this variable will also result in sharper images, making it easier to distinguish contact (Pueo., 2016). In addition to the frame rate, the quality of the images collected is also necessary. It is suggested that a resolution of 1920 × 1080 pixels is used to capture each frame (Pueo et al., 2020). This assessment method can be used in both the lab and field setting. However, immediate results are not provided analysis; must be done on the video file (can take as little as 30 seconds) (Balsalobre-Fernández et al., 2014). The cost of this equipment has gone down in recent years as technology has advanced to allow smartphones and downloadable software to be capable of now acquiring videos at higher frame rates (Dias et al., 2011). Additionally, the training experience of the user has become less of a barrier due to the software’s ease of use. Kinovea ™ is an example of a free and open-source tool practitioners may use (Pueo et al., 2020), while options such as Dartfish is a subscription-based tool that currently ranges from $7-165 per month (Dartfish). At the same time more robust camera models are available that range in price from $600-70,000 (Pueo., 2016).

PCMs determines jump height by calculating FT from when the signal between bars is established to when it is broken. Current brands of PCMs include: OptoJump, IR-mat, and ErgoJump Plus (García-López et al., 2013). Findings by García-López and colleagues (2013) observed that validated photocell mats (e.g., OptoJump and SportJump System Pro) are superior to contact mats because the error of the contact mats when measuring the flight time is less predictable. This error can be attributed to the hardness of the mat, participants' body mass, and jump height impacting the result of the equipment. Also, the PCMs allow for more ecologically valid results since the feet can directly contact the surface a sport is played on (i.e., basketball court or track [surfaces such as grass or sand disrupt the lasers and make use of them difficult to obtain results]), increasing its content validity (Glatthorn et al., 2011). On top of being an option for testing in the field (or lab) testing due to its portability and ease of handling, systems like OptoJump are less expensive costing ~$2,500 vs. ~$20,000-50,000 for a portable force plate (Glatthorn et al., 2011).

Contact mats consist of electric circuits that are mechanically activated when the material is compressed from the participant stepping on it, and once they leave the mat, an internal mechanism will begin to determine the FT until the individual lands again. Current brands of contact mats include ErgoJump, SportJump-v1.0, Just Jump, Newtest, or FLS JumpMat (García-López et al., 2013). There are a few drawbacks to this method:

- Because compression is needed to activate the mat, it will take time for the material to compress when the participant is landing, potentially increasing the amount of time the equipment perceives the person is in the air
- This equipment has been found to have some models that have errors with the calculation of FT (i.e., additional FT built in or an equation that deviates slightly from the previously listed equations)

Due to these equipment limitations, reliable results are obtained from most contact mats when compared to validated methods (Whitmer et al., 2015). However, there is a lack of validity in the results that will need to be accompanied by a correction equation to produce more accurate testing outcomes. Similar to PCMs, contact mats are easily transportable and are a simpler method for obtaining data from athletes, especially in large quantities (Kenny et al., 2012). Contact mats can range in cost from $500-800 with brands consisting of ErgoJump, SportJump, Just Jump, Newtest, or FLS JumpMat (García-López et al., 2013; Just Jump System; WebsiteNI).

An approach to resolving the issue of poor assessment tool validity, such as with contact mats, is by applying correction equations to equipment to obtain results that are more valid (Attia et al., 2017; Glatthorn et al., 2011; McMahon 2016; Whitmer et al., 2015). Each assessment tool will have its own correction equation if the same test is being conducted and when different equipment is used to validate it (e.g., two different brands of force plates used to validate the same contact mat or one force plate used to validate two different brands of contact mats). Additionally, similar tests (i.e., jump variations: static, countermovement, and countermovement with arms) will each need their own correction due to differences in how the motions are performed (Attia et al., 2017). When using equipment to collect data, it is important to understand the reliability and validity of the tools that are used. The correction equations gained from conducting validity comparisons allow practitioners to use more ecologically feasible approaches to collecting jump data (acquiring data where the athlete is, as well as on the surface they will compete/train on). It is recommended that performances measured on the particular equipment listed can be corrected to reflect force plate JH using the appropriate correction equation. Practitioners should consider the range of approaches for data collection, the strengths, and weaknesses of each tool, and if there is a need for developing effective corrections when using available resources. However, while the accuracy of jump mats can be questioned, most provide reliable measurements and can be used to gauge improvement (Pueo et al. 2016).

The Sargent (or Vertical) Jump test is performed by having the person stand with their side to a wall and reach up with the hand closest to the wall. Participants are to keep their feet flat on the ground. Standing height is the distance from the floor to the tip of the outstretched middle fingers to the nearest 0.1 cm. This measurement is repeated at least twice and averaged to reduce error. If the first two measures are not within 0.3 cm a third measurement is taken, and the mean of the closest two measures is recorded. The athlete puts chalk on their fingertips to mark the wall at the height of their jump. The athlete then stands away from the wall and jumps vertically as high as possible using both arms and legs to assist in projecting the body upwards, attempting to touch the wall at the highest point of the jump. The difference in distance between the standing reach height and the jump height is the score. The best of three attempts is recorded (Vertical Jump Test [Sargent Jump] — PT Direct). This is a cost -effective and time-efficient method to obtain a direct measurement of vertical power (which may be obtained with a prediction equation). The primary disadvantages of this method are that technique plays a part in maximizing your score, as the person must time the jump so that the wall is marked at the peak of the jump. This test can also be performed with a Vertec. Vertec measures height in ½ inch increments and has the capability of measuring jump from 6’ to 12’ (Vertical jump –Power Systems). This equipment is good for both field and lab testing (provided that the lab is of adequate height). Typical set-up and assessment with this equipment is a couple minutes and athletes can get assessed in a similar timeframe. The protocols for testing with this equipment follow the same procedures as the Sargent Jump test that involved the chalk on the fingertips. The Vertec ranges in price from ~$400-900. Both jump assessments can be performed in a field-based setting. One limitation of these assessments is that athletes will be limited to how they are loaded for weighted conditions, however, a simple workaround for this may be possible with a vest.

Developing recommendations for assessing VJH is largely based on the cost of the equipment, the time required for testing, the metrics you wish to examine, and where you intend to conduct the data collection. There will always be some degree of drawback(s) with the approach selected for VJH testing, but it is important to evaluate what best suits your needs. While VJH may be used as a daily monitoring tool, it should be used before exercise/training takes place (Cormack & Coutts., 2021b). Without access to specific laboratory equipment, using contact mats is the most cost-effective approach to obtaining reliable VJH data, though it may not be valid. Regardless of the selected method, developing a standardized protocol for warming up the athlete and conducting the test with consistency is paramount for obtaining meaningful data. An example would be standardizing the general warm-up before the test (e.g., 25 jumping jacks, 1x5 20kg mid-thigh pulls, and 3x5 40/60kg mid-thigh pulls female/male), while a specific standardized warm-up for vertical jump (e.g. unweighted 50% warm-up jump for a SJ, followed by 75% for that same jump type, with all following changes to weight conditions and jump type being preceded by a 75% warm-up of that condition and type). Information provided in Table 4.3 provides details on the previously mentioned VJH assessments so the best testing modality may be selected.

Table 4.3.

Characteristics of Methods for Assessing Vertical Jump Height

Assessment	Variable(s)	Limitations	Precision/ Reliability	Cost	Administrator skill required	Time required	Lab vs Field
Accelerometers	JH, vertical force (Fv), power (P), leg stiffness (kleg), and reactivity index (RI)	Cost, placement on the participant needs to be standardized	4	$40-20,000	2	2:00-5:00	Both
Chalk on fingertips	VJH (cm)	Only provides jump height, but can use prediction equation to estimate power	4	$15-20	1	2:00-5:00	Field
Force Plates	VJH (cm), PP, PF, RFD	Too low of sampling rate (<200 hz), cost, limited mobility for many models	5	$500-50,000	2 to 4	2:00 - 10:00	Lab
High Speed Video	VJH (cm)	Lighting quality, consistent and adequate distance of filming, too low of a sampling rate (<200 fps), and having a reference item in frame	4	free-$70,000	2	1:00-8:00	Both
Contact Mat	VJH (cm)	It will take time for the material to compress when the participant is landing to activate the mat, potentially increasing the amount of time the equipment perceives the person is in the air and some models that have errors with the calculation of FT	3	$500-800	1	:30-2:00	Both
Linear Position Transducers	VJH (cm), duration of contraction, $\bar{x}$ and PV, peak accel, $\bar{x}$ and PF, $\bar{x}$ and PP, instantaneous power, force at 30 and 100 ms, total imp, and total work done	Space to set up equipment. Many (4) are needed for more valid results	5	$570-3000	3	2:00-10:00	Both
Photo Electric Cells	VJH (cm)	Different models of this method all come with a high price tag	4	$2,500	2	:30- 8:00	Both
Vertec (Sargent Jump Test)	VJH (cm)	Only provides jump height, but can use prediction equation to estimate power	4	$400-500	1	2:00-5:00	Both

Muscular Strength Tests

The importance of increasing muscular strength is twofold: 1) no movement can occur without the use of some level of maximum, 2) there are strong relationships between maximum strength, RFD, and power output (Stone et al. 2022, Suchomel et al., 2018). Additionally, maximum strength is related to the following (Andersen & Aagaard 2006; Cormie et al., 2010; Doan et al. 2006; Folland et al. 2014; Semmler et al. 2004; Stone et al. 2007):

- a greater magnitude of force production (greater peak and average forces
- allowing for higher velocities and power outputs to be achieved with submaximal loads), greater RFD (allowing for faster muscle activation, greater force during critical time periods)
- greater and more efficient motor unit synchronization (think ballistic movements), superior ability to develop and respond to stretch shortening cycles (SSC)
- greater peak and average power (or work getting accomplished at a higher rate)
- greater absolute endurance (especially High Intensity Exercise Endurance, allowing for more total work can be accomplished due to reducing central nervous system fatigue)
- greater postural strength (or superior balance, hold static and dynamic positions better during performance)
- possibly becoming more sensitive to force and sensation (the ability to appropriately modulate force production is superior [may be a result of strength training partially independent of maximum strength]).

Sporting activities in which maximal strength is related to includes sprint performance, jumping, agility capability, and throwing performance (Baker & Nance., 1999; Bert et al., 2002; Cronin, J. B., & Hansen., 2005; Hori et al., 2009; Stone et al., 2003).

Muscular strength is the result of force production by specific muscles (or muscle groups) and is impacted by the composition of the fibers, the size of the muscle, muscle architecture, and how the neuromuscular system is innervated into it (Fukuda., 2019). Common metrics in muscular strength tests include absolute and relative PF. Relative PF using a scaling factor so that you can compare athletes of different body sizes. Allometrically scaled PF (PF x Body Mass

$^{-0.67}$) is the normalized kilogram per kilogram strength of the athlete. PF is associated with superior sport performance and dynamic strength measures. Impulse (or Force x Time) has a good relationship to dynamic characteristics and sport performance. RFD (or N x s^{-1}) is responsible for alterations in force during critical time periods/ranges of motion in sport activities (Haff et al., 1997; Lum et al., 2020). RFD is a beneficial metric sensitive to acute and long-term fatigue, exercise-induced tissue damage, and increased strength and power from longitudinal training (Haff et al., 1997; Lum et al., 2020).

Maximum strength can be measured in a few different ways. Either in a dynamic or isometric fashion and with multiple joins involved or a single one (McGuigan et al., 2010; Newton et al., 2011). While there are also conditions for using single joint assessment, this application is mostly in the clinical setting and is not covered further. Dynamic strength assessment achieved with one repetition maximum (1RM) testing can be specific to training, has moderate to strong relationships with sport performance while also having good reliability, and can be used with potentiometers and force plates (Drake et al., 2017; Giles et al., 2022; Guppy et al., 2018; Stone et al., 2019). However, dynamic 1RM testing requires greater familiarity than isometric testing, the true maximum can be missed, dynamic tests can be quite fatiguing and time consuming, particularly when multi-joint assessments are used (Drake et al., 2017; Giles et al., 2022; Guppy et al., 2018; Stone et al., 2019). The strengths of the isometric assessment includes requiring less familiarization, has moderate to very strong correlations with dynamic 1RM tests and sports performance, maximum force production is less likely to be missed (since force plates can more accurately capture the achieved output), it is less fatiguing than dynamic 1RM, takes less time consuming than 1RM, and the obtained PF has excellent reliability, with the only downside being is that this approach is less specific due to its static nature (Drake et al., 2017; Giles et al., 2022; Guppy et al., 2018; Stone et al., 2019; Stone et al., 2022b).

Dynamic strength assessments are relatively inexpensive to conduct, as long as the equipment is available (bar, weights, and rack) and can be very specific to training (Haff., 2018). This means of assessing strength can relate to various muscle actions (i.e., concentric, eccentric, or plyometric [the most typical of 1RM testing]) (Haff., 2018). Typically, a 1RM assessment method is used in dynamic strength testing, during which a participant will begin with a light warm-up and progress gradually to a heavy load, decreasing their reps performed in each set until a moderately heavy load is achieved (DeWeese et al., 2015; Haff., 2018; Newton et al., 2011). From there, smaller weight increments are added until the participant fails. Three repetition maximum multiple repetition RM estimates have been used as options to assess strength or strength endurance respectively (McGuigan et al., 2013; Haff & Dumke., 2022). Common multi-joint lifts for 1-RM testing include back squat, bench press, and power clean (Brown et al., 2013; Haff & Haff., 2012). 1RM testing typically takes 20-25 minutes , with a warmup included, and can have a setup that allows multiple athletes to be assessed simultaneously. However, force-time curves can still be effectively paired with the results from dynamic strength tests if force plates are used. While typically considered a field test, with force plates, dynamic strength testing can often be confined to a lab unless the force plates are portable and appropriate flooring is available. Additionally, this means of assessment can under-predict actual strength due to inaccurately/miscalculating incremental load increases for the test exercise. Typical dynamic strength testing will take ~15 to 30 minutes depending upon the athlete's strength levels and need for rest between attempts.

Isometric testing can range in cost (~$500-50,000 price of FPs and ~$3,100 rack set up) and include tests such as the isometric med-thigh pull (IMTP), isometric squat (ISQT), isometric leg press (ILP), and the isometric bench press and (IBP) (Haff., 2018), Of these assessments the IMTP has been shown to have substantial association with to sport performance, and is constantly getting fine-tuned to become more practical in field testing. The IMPT is the safest of the lower body assessments to perform (Eserhaut et al., 2023; Haff., 2018). It is important to ensure the athlete achieves the standardized set-up each time they perform the test. Additionally, this type of strength assessment should be conducted in a position corresponding to the actual sporting movement with multiple joints involved. This is accomplished by setting up joint angles similar to positions the athlete will be in, that give the highest values. There is evidence to suggest that use of isometric strength assessment for abduction and adduction of the hip may be relevant to ice skating performance (Secomb et al., 2021). The use of isometric conditions also reduces the likelihood of injuries occurring (Brown & Weir., 2001). Finally, the time of this assessment can range from ~7-15 minutes (which is largely dependent on the quantity of trials the participant performs). Typically, the IMTP is a more efficient lower body strength assessment to perform. This is largely due to the extensive amount of research that has been used to standardize this test (Comfort et al., 2019; Haff et al., 1997; Haff et al., 2005). The major checkpoints you want to ensure when you set the athlete up on the fixed bar include:

- Foot spacing between hip and shoulder width
- Knee angle of 125° ± 5°
- Barbell resting on the upper 1/3 of the thighs
- Hand spacing outside shoulder width, knuckles down
- Arms and wrists straight, shoulders retracted and depressed
- Upright torso position
- Head up

Further, grip strength can be a limiting factor during this assessment so securing the athlete's hands to the bar with a lifting strap and athletic tape is the current recommendation.

When performing both dynamic and isometric assessments of strength it is important that participants wear shoes that allow for appropriate stability and force transmission during the test. Shoes with an excessive or soft sole are discouraged, due to the time it takes for the material to deform and better transmit force. This issue can be eliminated by the use of weightlifting shoes. This type of shoe has a hardened sole that can better transmit force and is ridged enough to resist severe deformation.

For all testing, particularly strength testing, one aspect of testing of importance is trained investigators (testers). The investigators should understand all of the nuances of the tests as well as environmental safety factors. For multi-joint tests in particular, it is paramount that the investigators are familiar with good technique and the attributes of a successful test (e.g. squat depth).

Table 4.4.

Characteristics of Methods for Assessing Maximal Strength

Assessment	**Variable(s)**	**Limitations**	**Precision/ Reliability**	**Cost**	**Administrator skill required**	**Time required**	**Lab vs Field**
Isometric Mid-Thigh Pull	PF, RFD, Impulse, PFa	Space needed and cost of set up	5	$4,100-60,000	2 to 4	7:00-15:00	Lab
Dynamic 1RM Testing	PF, Pfa	Space and equipment needed	3	Free (if infrastructure is already present) - $600	2	20:00-25:00	Both
Dynamic 1RM Testing with Force Plates	PF, RFD, Impulse, PFa	Cost as well as space and equipment needed	4	$1,600-50,600	2 to 4	20:00-35:00	Lab

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Chapter 5. Summary and Conclusion

The primary purpose of this investigation is to evaluate the effectiveness of a questionnaire designed to assess coaches' perceptions of an athlete assessment program. The findings from this study indicate that the modified questionnaire is a reliable tool that can be used for future assessment of coaches' perceptions related to constructs that relate to influence, applicability, understanding, and returning data. The questionnaire identified aspects that may be improved upon in ETSU's CESSCE SPEG program. Areas of improvement include the influence of monitoring results and incorporating assessments and context that better reflect the performance of the athletes in their respective sports. Enhancing the influence of monitoring results may be accomplished with more detailed reports and in-person delivery from the sport scientist on relevant points. This format for returning data to the coach would allow for the opportunity to better convey information to the coach, which can help enhance decision-making. With regard to having the assessments better reflect sport performance, this may improve in two ways. First, the inclusion of more sport specific tests to better identify key performance indicators relative to the sport. The second way is by relating current assessments back to strength & conditioning or sport specific performance, then the coach can better understand with the additional context how these assessments reflect performance.

The tertiary purpose of the dissertation was to develop a guide for practitioners with resources to better approach the logistics for organizing their own athlete assessment program. This included context related to the importance of assessing athlete performance with key features of fatigue management and program efficacy. Logistics prior to data collection covered informing athletes of the purpose of the assessment, obtaining informed consent, and medical clearance. Factors related to the assessment include ensuring it is adequately staffed and the personnel are well trained, selecting adequate equipment to collect data, duration of the assessment, and data management are all appropriately implemented in advance. Athletes who partake in the assessments need familiarization of procedures, awareness of expectations, and taken through the assessments in a logical order so the fatigue from a previous test does not impact later performance. Finally, details related to hydration, body composition, vertical jump height, and maximal strength were covered so practitioners may better select these assessment methods based on information related to the variable(s) each tool collects, their limitations, its precision/reliability, cost, invasiveness (when applicable), administrator skill required, time required, and where it has application the lab vs the field.

Future Directions

Related to the questionnaire, future research should aim to implement this questionnaire or a similar tool at other institutions that share a similar structure or within the realm of professional sports. Additional measure of the questionnaire's effectiveness should examine the difference in responses between individual and team sports, in-season and off-season teams, and how outcomes from a team's season may impact the coach's perception of the assessment program.

The monitoring methods covered in this dissertation are only a few of the many that are available. Over time, new methods are being developed and current approaches are being refined. The use of technology in sport has helped to enhance the overall performance of athlete's speed, mechanical efficiency, and safety when developing training and planning approaches to sessions. Future areas of research can include assessing the range of timing methods (stop watch, timing gates, etc.), assessment of aerobic capabilities (yo-yo test, time trials, metabolic cart, submaximal step test, Max VO2, Lactate Threshold) (especially as they relate to different sports/circumstances), sprints, change of direction and agility (505, T-test, 3 cone drill, hexagon agility test), IsoPress (seated, supine bench, incline bench), throwing velocity (baseball, softball), and regular monitoring methods (heart rate, blood pressure, fluid loss, internal training load, external training load, perceptual well-being), and blood work.

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APPENDIX: Coach Questionnaire

Sport Testing & Monitoring Survey

Sport:	**Name:**					
For each item below, circle the number that best fits your judgment of its quality.						
This is a **voluntary** research study in which you will be answering questions regarding the current approach towards testing and monitoring your team's performance. Your answers to these questions are based on the training your athletes received directly from the Sport Scientist and/or Strength and Conditioning Coach you work with. Upon completing this questionnaire, you will be asked to complete the same questionnaire within 48 hours of completing the first. After completing the first questionnaire you may contact **David Fish** for pick up or turn it into the Mini Dome, Room E139. Upon returning the first questionnaire, you will receive the second. If you have any questions **please email David Fish at fishdj@etsu.edu**.						
Please note that questions below will pertain to testing, monitoring, or both. Those parts of the questions are underlined.						
Testing- beginning, middle, or end of season data collection that requires maximum effort or ability (e.g., Yo-Yo test, isometric mid-thigh pull, or body composition)	Monitoring- daily or weekly data collection that with the goal of watching, keeping track of, or checking athlete's current state (e.g., readiness questionnaire, training session report, unweighted jumps)					
Answer the following questions using this scale: SD = Strongly Disagree, D = Disagree, N = Neutral, SA = Strongly Agree, N/A = Not Applicable	**SD**	**D**	**N**	**A**	**SA**	**N/A**
1. Data obtained from the current testing program is used to alter my athlete's individual strength and conditioning program.	1	2	3	4	5	0
2. Data obtained from the current monitoring program is used to alter my athlete's individual strength and conditioning program.	1	2	3	4	5	0
3. Data obtained from the current testing program is considered when practices are being developed.	1	2	3	4	5	0
4. Data obtained from the current monitoring program is considered when practices are being developed.	1	2	3	4	5	0
5. I understand why my athletes participate in the current testing procedures (list all procedures: ______________________________).	1	2	3	4	5	0
6. I understand why my athletes participate in the current monitoring procedures (list all procedures:______________________________).	1	2	3	4	5	0
7. Data obtained from the current testing procedures reflects my athletes' on-field performance well.	1	2	3	4	5	0
8. Data obtained from the current monitoring procedures reflects my athletes' on-field performance well.	1	2	3	4	5	0
9. If I were to take a job at another organization, I would want to take the current testing/monitoring program theory with me.	1	2	3	4	5	0
10. The current testing/monitoring program helps my athletes perform to their greatest potential.	1	2	3	4	5	0
11. I am satisfied with the current testing/monitoring program.	1	2	3	4	5	0
12. Information acquired from testing/monitoring is reported to the team.	1	2	3	4	5	0
13. I was able to understand the information that was presented in the data report(s) I received.	1	2	3	4	5	0
14. I am comfortable asking the Sport Scientist/Strength & Conditioning Coach to provide more information about the testing/monitoring results.	1	2	3	4	5	0
15. I am able to ask questions to the Sport Scientist/ Strength & Conditioning Coach about the data that was collected.	1	2	3	4	5	0
16. Information acquired from testing/monitoring is reported to the *appropriate* staff (*coaches, sports med, etc.*).	1	2	3	4	5	0
17. In response to item 16, the mode I most often received the report of the data was (select one): A) Team meeting B) Written Report C) Other Coaches D) Testing/Monitoring Personnel E) In Passing						
18. In response to item 17, what are the remaining modes you receive reports of the data: A) Team meeting B) Written Report C) Other Coaches D) Testing/Monitoring Personnel E) In Passing						
19. How soon after data collection do you receive a testing report/return? A) Within 48 hours B) 48 hours - 1 Week C) 1-2 Weeks D) 2-3 Weeks E) If timeframe isn't listed, please provide: ______________________________						
20. How soon after data collection do you receive a monitoring report/return? A) Within 1 hour of practice B) Within 2-4 hours of practice C) Within 4-6 hours of practice D) If timeframe isn't listed, please provide ________________ E) Not applicable						
21. How frequently does your team collect testing data? A) 1-2 times a year B) 3-4 times a year C) 5-6 times a year D) If frequency isn't listed, please provide: ______________________________						
22. How frequently does your team collect monitoring data? A) Daily B) Weekly C) If frequency isn't listed, please provide: D) Not applicable ______________________________						

VITA

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	B.A. PE Sport and Fitness Instruction, Carthage College, Kenosha, Wisconsin, 2018
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	Graduate Assistant, East Tennessee State University, Education Leadership and Policy Analysis, 2019-2021
Publications:	Fish, David John. (2021). "Implementing of Phase Potentiation Program with College Triathletes."
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