Module 2. Physical and Physiological Key Performance Indicators

Years ago, physicality was quantified by measuring five fundamental fitness variables: muscular strength, muscular endurance, flexibility, cardiorespiratory fitness, and body composition (American College of Sports Medicine, 2013). However, it should be noted that these components of fitness were a means to assess the mass population. More recently, exercise physiologists and fitness experts have come to agree that other factors such as muscular power, coordination, balance, and anaerobic power should be included to measure physicality as accurate as possible. However, it is interesting to note that this is not novel, as in the early 1960s, Nicks and Fleishman (1960), being ahead of their time, sought to include additional variables to be considered measures of physicality: muscular strength, muscular power, muscular endurance, static flexibility, dynamic flexibility, coordination, balance, anaerobic power, cardiorespiratory endurance, and agility, see the table below. The most recent addition includes Martin's (2016) comprehensive measurement model that includes physical, psychosocial, physiological, behavioural, and environmental variables in a model for sports performance prediction.

As a sports scientist, it is fundamental to be aware of physical key performance indicators (KPIs). The most commonly assessed in professional sports are: body composition, muscular strength, power and endurance, flexibility, balance, anaerobic power, aerobic power, reaction time, agility, and level of sport-specific skill.

Table 1: Physical measures and fitness models

Fundamental Five-Component Model	Expanded Model (Nicks and Fleishman 1960)
Muscular strength	Strength (explosive, dynamic, and static strength)
Muscular endurance	Coordination (multiple limb and gross body coordination)
Flexibility	Flexibility (extent and dynamic flexibility)
Cardiorespiratory endurance	Running speed
Body composition	Balance and agility

Source: Martin, 2016.

In order to obtain a more accurate predictive model of sport performance, it is also critical to include the quantification of physiological measures, such as resting and active heart rate, heart rate variability, blood pressure, lactate threshold, insulin and glucose levels, vision assessment, and telomere length (Martin, 2016). These physiological variables reflect the internal state of the athlete's body and yield a better overall picture of the body's engine, how it is running and why it runs the way it does.

Body composition can be defined as the proportion of muscle, fat, bone, and other substances in the athlete's body. A superficial and quick method for assessing body composition is the body mass index (BMI). This is most commonly captured by the medical doctors, but for professional athletes, this is not an accurate assessment of body composition. Most athletes have greater lean body mass than the general population, and that skews the body mass index calculation, yielding inaccurate results. Typically, BMI is used to calculate an individual's fat content based on the relationship between a person's height and weight.

BMI is calculated as the weight in kilograms (kg) divided by the height in meters squared (m^2):

Formula for BMI: weight (kg) / $[\text{height (m)}]^2$

Formula: weight (lb) / $[\text{height (in)}]^2$ x 703

For example, the BMI of a female athlete weighing 136 pounds (61.69 kg), who is five feet four inches tall, is calculated by first converting the weight into kilograms (61.7) and height to meters (1.62). Second, determine the square of the height, which is 1.62 × 1.62 = 2.6244 meters squared. Finally, divide the weight in kilograms by height in meters squared. It is important to note that BMI is used most often for clinical purposes, to assess patients who may not be as physically active or involved in sports as athletes are. When BMI is used to assess an athlete's body composition, the majority of the time, the BMI falls in the overweight or obese categories because of an athlete's increased muscularity compared with other individuals.

Another method of examining body composition is by assessing fat distribution in the athlete's body. A typical way to measure fat distribution is by using the waist to hip girth ratio method, where the waist circumference is divided by the hip circumference. This is easily assessed using spring-loaded tape and measuring the waist mid-way between the lowest rib and the iliac crest, a common landmark used as a reference is the narrowest part near the belly button area. The hip circumference is measured at the level of the greater trochanters; a landmark commonly used as a reference is the widest part of the hips.

Finally, the most accurate measure of body composition is to obtain an assessment of the body fat of the athlete. More precise measures of body composition compartmentalise parts of the body into either fat or lean tissue, which includes, muscles, organs, and bones.

It is important to understand that fat weighs less than muscle. I am sure you have heard the phrase, “muscle weighs more than fat”… but what does this actually mean? This is derived from the knowledge that muscle is, in fact, denser than fat, and thereby weighs more per cm3.

Body density is typically assessed through underwater weighing, the official name being hydrodensitometry (hydrostatic weighing), which is based on the Archimedes’ principle. It states that a partially or fully submerged object will experience an upward buoyant force equal to the weight or the volume of fluid displaced by the object. The protocol for underwater weighing includes having the athlete step into a gigantic water bath where they can be submerged. The amount of water that is displaced is noted, as it will be inserted into an equation along with the known density of water, 1g/cm3, in order to calculate body density. For detailed protocol on hydrostatic weighing and calculations, please refer to the Haff and Dumke 2012 Laboratory Manual for Exercise Physiology.

Table 2: Body density equations used to calculate body fat percentage

Measurement Option	MEN	WOMEN
Option A: 3 site Men = chest, abdomen, and thigh Women = triceps, suprailiac, and thigh	Body Density (BD) = 1.10938 - 0.0008267 (multiply by the sum of three skinfolds) + 0.0000016 (sum of three skinfolds)2 - 0.0002574(age) [SEE = 0.008]	Body Density (BD) = 1.099421 - 0.0009929 (multiply by the sum of three skinfolds) + 0.0000023 (sum of three skinfolds)2 - 0.0001392(age) [SEE = 0.009]
Option B: 3 site Men = chest, triceps, and subscapular Women = triceps, suprailiac, and abdominal	Body Density (BD) = 1.1125025 - 0.0013125 (multiply by the sum of three skinfolds) + 0.0000055 (sum of three skinfolds)2 - 0.000244(age) [SEE = 0.008]	Body Density (BD) = 1.089733 - 0.0009245 (multiply by the sum of three skinfolds) + 0.0000025 (sum of three skinfolds)2 - 0.0000979(age) [SEE = 0.009]
Option C: 7 site Men = chest, midaxillary, triceps, subscapular, abdomen, suprailiac, and thigh Women = chest, midaxillary, triceps, subscapular, abdomen, suprailiac, and thigh	Body Density (BD) = 1.112 - 0.00043499 (multiply by the sum of seven skinfolds) + 0.00000055 (sum of seven skinfolds)2 - 0.00028826(age) [SEE = 0.008]	Body Density (BD) = 1.097 - 0.00046971 (multiply by the sum of seven skinfolds) + 0.00000056 (sum of seven skinfolds)2 - 0.00012828(age) [SEE = 0.008]

Source: Haff and Dumke, 2012 and American College of Sports Medicine, 2013.

Another method that is common is the non-invasive method with a bioelectrical impedance machine. These machines work by sending multiple electrical currents through the body and assessing the amount of impedance throughout the body. This analysis is based on the fact that tissues with high water content act as a conductor of electrical current, whereas fat tissue impedes electrical conductivity (Heyward, 2004; Lukaski, 1995). Typical values of body fat percentage can be seen in the table below.

Table 3: Body fat percentage categories

Category	Men	Women
Essential fat	2-4%	10-12%
Athletes	6-13%	14-20%
Fitness	14-17%	21-24%
Acceptable	18-25%	25-31%
Obese	26% or >	32% or >

Source: American College of Sports Medicine, 2013.

Another method of assessing body fat is through the use of skinfold callipers. Below is also a table of the body fat percentage categories. The protocol includes obtaining two consecutive measurements at three, four, or seven designated sites of the body made by the same investigator on the right side of the body and recorded to the nearest millimetres with rest intervals of at least 15 seconds before taking subsequent measurements. If the second measurement varies by more than 2 mm, a third measurement should be made to ensure accuracy. Several equations may be used depending on whether body fat was assessed in three, five, or seven areas. It is also important to note that when using this method, the equations slightly differ between sexes. Please refer to ACSM's Guidelines for Exercise Testing and Prescription for details on how to assess the different sites on the body when conducting either a three, four, or seven site skinfold assessment (Heyward, 2004; American College of Sports Medicine, 2013).

Muscular Strength

Muscular strength is the maximum amount of force that can be generated by a particular muscle, or group of muscles, during contraction. The most accurate assessment that is used to assess upper and lower body strength is the one repetition maximum (1RM), which is the maximum amount of force that can be lifted in one repetition. However, a major note of caution, with professional athletes, you do not typically want to have them go all out and perform a one repetition maximum as there is high risk of injury. Moreover, muscular strength assessments should not be conducted on an elite athlete if he has had a previous injury or if he runs the risk of a recurring injury to a vulnerable muscle. If there is a risk of injury or safety concern, it is better to obtain a submaximal assessment of muscular strength, using a four or eight repetition maximum (4RM or 8RM), the maximum amount of force that can be lifted for four or eight repetitions, in order to estimate and reasonably predict the 1RM of the athlete. See the tables below (repetition maximum coefficients and repetition maximum values) for additional information on repetition maximum coefficients and predictive ability. For the 1RM, the athlete should complete a warm-up set for each muscle the coach is seeking to test.

Below is a sample protocol for obtaining the 1RM, from Essentials of Strength Training and Conditioning (Baechle and Earle, 2008):

1. Determine whether the athlete is to perform the 1RM, or a submaximal lift of 4RM, 6RM, or 8RM with which to predict the 1RM. (This should be based on the view of the coaches or physical therapist with respect to the risk of injury, type of sport, or the muscle group of interest).

2. Have the athlete warm up by completing a number of submaximal repetitions at roughly fifty to seventy percent of the athlete's perceived capacity for the muscle, or muscle group, to be tested.

3. Have the athlete conduct four trials, with three- to five-minute rest intervals between each trial.

4. If the athlete is to perform the 1RM, he or she should be instructed to rest for four minutes before the load is increased by ten to twenty pounds, or five to ten percent for upper body exercise, and by thirty to forty pounds, or ten to twenty percent, for lower body exercise until the 1RM is reached for the specified muscle or muscle group.

5. If the athlete fails to lift the weight, the load should be reduced by five to ten pounds or two-and-one-half to five percent for upper body exercise, and fifteen to twenty pounds, or five to ten percent, for lower body exercises.

Table 4: Repetition maximum coefficients

Number of Repetitions	Squat/Leg Press Coefficient	Bench/Chest Press Coefficient
1	1	1
2	1.05	1.04
3	1.13	1.08
4	1.16	1.12
5	1.2	1.15
6	1.24	1.18
7	1.28	1.22
8	1.33	1.26
9	1.37	1.29
10	1.41	1.33

Source: Baechle and Earle, 2008.

Table 5: Repetition maximum values

Repetitions	% 1RM
1	100
2	95
3	93
4	90
5	87
6	85
7	83
8	80
9	77
10	75
11	70
12	67

Source: Baechle and Earle, 2008.

Muscular Power

Muscular power is the ability of the muscle to exert a certain amount of force per unit of time, also referred to as explosiveness. Muscular power is a factor that all athletes must possess, whether it be to jump, sprint, or perform an explosive swing.

In laboratories, isokinetic machines are used to capture and assess muscular power by quantifying several measures, including peak torque, time to peak torque, peak torque slope, and power (work done/time). However, a more practical way to assess muscular power (if access to an isokinetic machine is limited) is to use either free weights, pneumatic machines, or standard resistance machines. This is done by using a low resistance weight that can be moved quickly through the entire range of motion of the exercise.

Muscular power assessments require performing a warm-up similar to that in the muscular strength test, but rather than determining the maximum weight that can be lifted, the objective is to have the athlete perform the repetitions as explosively as possible. The typical protocol entails having the athlete perform three repetitions as quickly and explosively as possible at forty-five to sixty-five percent of the athlete's 1RM for that particular muscle or muscle group. The outcome is quantified on the basis of the time required to perform the three repetitions as quickly as the athlete is able, as well as the percent of 1RM that is used. The theoretical concept behind this assessment is to examine the point in the force-velocity relationship that the athlete exhibits maximum power, so that it may later be applied in his sport (Martin, 2016).

Muscular Endurance

Muscular endurance is the ability of a muscle, or muscle group, to perform muscle actions repeatedly over a period of time until fatigue. Both absolute and relative muscular endurance are now routinely quantified and analysed. Absolute muscular endurance is quantified as the number of repetitions that can be performed at a designated percent repetition maximum for a given length of time. Relative muscular endurance is measured as a change in the athlete's muscular endurance over a period of time, such as occurs with training.

Muscular endurance is often captured by performing repeated muscular contractions until fatigue sets in, and can be tested for one minute or up to two full minutes. The athlete should perform as many repetitions as possible of a particular muscle or group, at low load, for example twenty-five to thirty-five percent of the athlete's 1RM. Another method commonly used to assess muscular endurance in athletes is to have them perform between twenty-five and thirty-five repetitions within a specified period, of either one or two minutes.

A note of caution, this type of assessment should not be conducted within the competition performance window of the athlete's program.

For abdominal muscle groups, the number of continuous crunches that an athlete can perform, without rest, is a good measure of abdominal muscular endurance (American College of Sports Medicine, 2013).

Flexibility

Flexibility is the ability to move a joint through a range of motion. Not only is flexibility important for activities of daily living, but it is also a crucial factor for athletic performance. Some sports require greater flexibility, such as gymnastics, basketball, and tennis. Several positions within team sports require greater flexibility than other player positions within the same sport; for instance, in soccer, the goalie position requires greater flexibility than a fullback. There are many field tests that can be used to assess flexibility such as the sit-and-reach test, back scratch test, trunk rotation test, and the functional reach test.

The **sit-and-reach test** is commonly used to assess hamstring and lower back flexibility. Athletes should be instructed to remove their shoes, sit on the floor with their legs fully extended, and feet flat against the sit and reach box. Then the athlete should be instructed to place one hand on top of the other and reach forward, while keeping the back straight and head up. Their reach should be held for approximately two seconds (without bouncing). Two practice trials followed by a test trial is typically used to obtain a reliable measure. The outcome is the length that was reached and held for two seconds on the sit-and-reach box (American College of Sports Medicine, 2013).

The **back scratch test** is commonly used to assess shoulder flexibility. Athletes are instructed to place their hand over their shoulder, and then reach as far down their back, with the palm of the hand facing the back, while simultaneously placing their other arm behind their back, reaching up as far as possible attempting to touch or overlap their hands and holding the reach for at least two seconds. The test is then repeated for the other side by switching the positions of the arms. A ruler is used to record the reach distance. If the athlete is not able to touch their fingers, a negative score is given, if the athlete reaches their hands, a zero is given, and if the athlete's fingers overlap they are given a positive score.

The **trunk rotation test** is used to measure rotational flexibility of the trunk. The athlete is instructed to start the test standing with the shoulders perpendicular to the wall. The athlete is then instructed to remove their shoes and to stand behind a tape line marked on the floor. The athlete is then instructed to rotate and reach as far as they can along a numbered scale mounted on the wall. Their performance is evaluated by measuring how far they are able to reach along the scale mounted on the wall. The same procedure is repeated on the other side of the body (Stanziano et al., 2009).

The **functional reach test** consists of having a numbered scale mounted on a wall (the only equipment needed to measure), athletes should remove their shoes, stand with the right shoulder parallel to the scale on the wall, fully extend the right arm horizontally with their hand closed in a fist, and hold this position for two seconds in order to have their standing reach recorded. Next, they should be instructed to lean forward as far as possible without lifting either heel off the ground, otherwise the test is disqualified. Functional reach is then calculated by subtracting the initial distance recorded from their leaning reaching distance. For example, if an athlete started off with the shoulder perpendicular to the wall at the 13-inch mark and then reached 34 inches (0.86 m), the reach is 34 minus 13, resulting in a total of 11 inches (27.94 cm). Then the same procedure is repeated on the other side of the body (Duncan et al., 1990).

It is important to note that if flexibility is to be assessed when an athlete is recovering from an injury, it is recommended that a more precise measurement of joint range of motion be assessed using a goniometer and following the protocols by (ACSM guidelines). For select single-joint range of movement, see the table below.

Table 6: Select single-joint range of movement ranges

Movement	Degrees
Shoulder Girdle Movement	
Flexion	90-120
Extension	20-60
Abduction	80-100
Horizontal abduction	30-45
Horizontal adduction	90-135
Medial rotation	70-90
Lateral rotation	70-90
Elbow Movement	
Flexion	135-160
Supination	75-90
Pronation	75-90
Trunk Movement	
Flexion	120-150
Extension	20-45
Lateral flexion	10-30
Rotation	20-40
Hip Movement	
Flexion	90-135
Extension	10-30
Abduction	30-50
Adduction	10-30
Medial rotation	30-45
Lateral rotation	45-60
Knee Movement	
Flexion	130-140
Extension	5-10
Ankle Movement	
Dorsiflexion	15-20
Plantarflexion	30-50
Inversion	10-30
Eversion	10-20

Source: ACSM guidelines (https://www.academia.edu/43653754/ACSM_guidelines)

Balance

Balance is another important factor that plays a role in sports performance. It is the ability to control equilibrium in the body. Within this module, we do not delve into the details of equilibrium and torque, if interested please refer to McLester and St. Pierre's Applied Biomechanics or Shamus's Atlas for Physical Therapy. For on the field practical assessments of balance, the following tests are most commonly implemented; the single leg stand, the balance error scoring system (BESS), and the star excursion balance test.

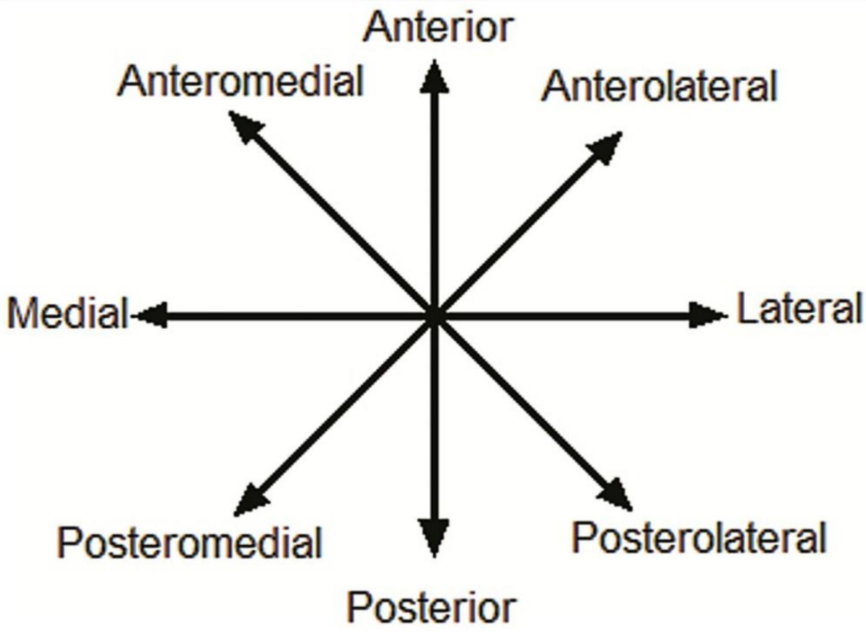
Another great way to quantify balance if available in the training facility is the Proprio reactive balance system.

Single leg stand. This is a commonly used field test used to assess balance. The athletes are instructed to stand with their feet together and with their arms down at the sides. Then they are asked to raise one foot about 6 to 8 inches off the ground by bending that leg at the knee and keeping both hands at their sides. They are informed that they should stand on one leg as long as possible, keeping the standing leg straight with their arms at the sides, and the other foot in one place as long as possible. Testers should be trained to stop the test when the client's arms either moves away from their sides, if the support foot moved across the floor, or if the participants' raised foot touched the floor. The outcome to be measured is the amount of time the athlete can remain balanced on each leg.

Balance Error Scoring System (BESS). This is another field test that is relatively inexpensive to quantify balance. The only equipment needed is a foam balance pad. This test consists of having six positions consisting of three stances (double-leg support, single-leg support, and tandem) that are held for 20 seconds on two surfaces (firm floor and foam pad) for six permutations (Riemann, Guskiewicz, and Shields, 1999). It is important to note that, during this test, the athlete's eyes should be closed, and their hands should be on their hips. They are to keep as steady as possible, and if they lose their balance, they are to try to regain the initial position as quickly as possible. Athletes are deducted a point for any of the following errors: lifting the hands off their hips, opening their eyes, stepping, stumbling, falling, or being out of position for five seconds (Riemann, Guskiewicz, and Shields, 1999). The scoring is as follows; 10 errors are allowed per position, any incomplete (not able to hold for at least five seconds) position results in a score of 10 for that position, the total score is a summation of all the number of errors for the six positions.

The Star Excursion Test. The star excursion test is another relatively inexpensive and simple assessment of balance for athletes. All that is needed is athletic tape, as it requires the floor to be marked in a star pattern consisting of eight directions, 45° apart from each other. The athlete is instructed to place one foot in the middle of the star pattern. Then they are instructed to reach as far as possible, sequentially (either clockwise or counterclockwise), in all eight directions. They are to tap the floor while maintaining balance, and then the distance from the centre of the star to the tap is measured. The athlete is disqualified if any of the following errors occur: rests the foot on the ground, loses balance, or makes an impulsive and heavy touch to the floor, or cannot return to the starting position under control (Kaminski and Gribble, 2003). Scoring of this assessment is the average of three trials.

Figure 1: Star Excursion Balance Test (SEBT)



Source: Public Library of Science, n.d., https://bit.ly/3qyifzt

A more novel assessment is the Proprio reactive balance system. It is usually conducted in a laboratory using a dynamic motion analysis system capable of assessing the athlete's centre of mass movement. It can also quantify trunk movement in six degrees of freedom – lateral, up/down, anterior/posterior, rotation, flexion/extension, and lateral flexion. The machine is simply a platform that can tilt in different angles as well as at different rates. Platform movement options include predictable motion, random motion, variable speeds (12.6◦ /s to 126◦ /s), and adjustable degrees of tilt motion (2◦ 25◦). Typically, a harness is attached to the frame of the unit and also attached to the athlete in order to help prevent injury. I have to say this is a great way to measure and assess different aspects of balance, however, access may be the limiting factor (Winkler and Esses, 2011).

Anaerobic Power

Anaerobic Power is one of the most important KPIs to quantify in athletes. Most sports specific movements require explosive motion that requires anaerobic power. The typical way to get an accurate assessment is by stressing the phosphagen (ATP-PC) system, where the anaerobic system is the primary source of energy. These tests are performed at very high intensities and performed for a very short duration, ranging from 10-30 seconds (ACSMs guidelines).

The following is a list of anaerobic tests that can be used to assess anaerobic power: sprints, countermovement vertical jump test, static vertical jump test, Bosco 60s continuous jump test, and the Wingate anaerobic cycle test.

Sprints are used to specifically assess horizontal power using the 30-yard dash, 40-yard dash, and 60-yard dash, the 40- and the 60-yard dash are assessed during the yearly NFL combine (Haff and Dumke, 2012). This is a simple field test where the only equipment needed to quantify the athlete's sprint time is a stopwatch, which have shown relatively strong correlations with electronic timers (r=0.98, r2=0.95, se = 0.24). To be even more precise, you can use the following equation:

Electronic timer time (s) = 1.0113 X stopwatch time (s) +0.2252

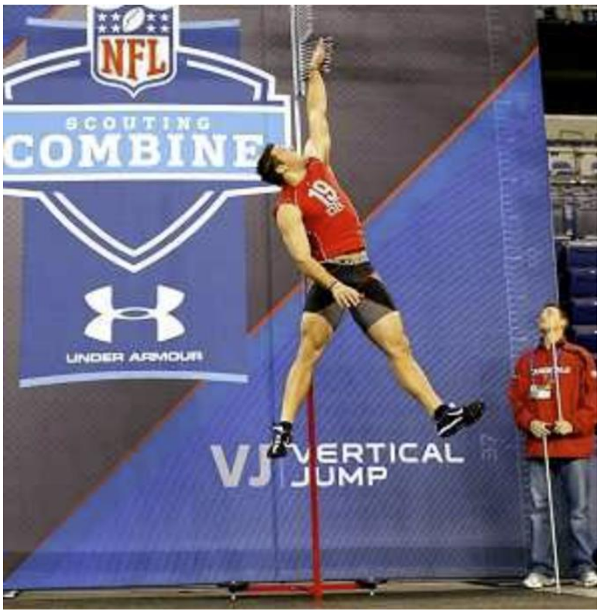
Figure 2: The velocity continuum in soccer players

Source: Soccer 11, n.d., https://bit.ly/3B8xwf4

The countermovement vertical jump test assesses the athlete's vertical power, which has been strongly correlated with sports performance (Haff and Dumke, 2012). This particular jump test is dynamic in the sense that the athlete is instructed to start in a standing position shoulder width apart, drop into a squat position and then (using momentum) jump as high as possible.

Contrary to the countermovement jump, a static vertical jump removes the confounding factor of momentum by having the athlete drop to the squat position and hold that position for at least three seconds and then jumping as high as possible.

Figure 3: Average vertical jump norms and scores



Source: Home Exercise Equipment Central, n.d., https://bit.ly/3xiSUNK

The scoring for both the countermovement jump and static jump is vertical displacement. The method of obtaining this value using inexpensive equipment is to have each individual athlete reach as high as possible with their palm against a scale marked on a wall (or other area), then mark the point that they initially used as a starting point and then instruct the athlete to perform either of the tests and reach for the highest point possible while jumping. The vertical jump displacement score is the difference between the standing reach height and maximal height reached when they performed the jump.

Vertical displacement (cm) = jump height (cm) – reach height (cm)

Vertical displacement can also be assessed in the laboratory using a force plate. In this case, the athlete performs the vertical jump tests on top of the force plate. Vertical displacement is then calculated using a formula that includes gravity and the amount of time the athlete is in the air (Haff and Dumke, 2012).

The Bosco 60s continuous jump test is an assessment that is often used to assess anaerobic power, however, in reality, it is a great measure of anaerobic power and anaerobic endurance as it measures the ability to perform high power movements repeatedly (Haff and Dumke, 2012). It can be designed to last anywhere between 15 seconds to 60 seconds. Depending on the sport, a 15-second test may be more relevant to examine, for instance, for a sprinter, whereas for a running back 60 seconds may yield a better prediction for their sport performance. The athlete is instructed to jump as high as quick as possible for the designated time. The outcome is the result of the number of jumps completed and the sum of the flight times. Quick note, it is much easier to quantify if done on a force plate, as flight is easily captured, otherwise please refer to Haff and

Dumke (2012) for formulas and equations that will be required to extrapolate power output from this test.

The Wingate Anaerobic Cycle test (WAnT) is another assessment used to quantify anaerobic power. This is usually performed in a laboratory and was originally performed for a 30-second duration against 0.075 kp per kg of body mass (Haff and Dumke, 2012). Research shows that the first 3-15 seconds of the test exhaust the ATP-PC system and that the glycolytic systems are used for the remainder of the test. The cycle is connected to a software system that yields peak anaerobic output, the moment where the highest power is generated, which typically occurs within the first 5 seconds of the test.

Aerobic Power

Aerobic power is also referred to as aerobic capacity, cardiovascular endurance, or cardiorespiratory fitness (CRF). Aerobic power is the ability to perform moderate to vigorous intensity exercise for prolonged periods of time and is a reflection of the functionality of three systems: cardiovascular, pulmonary, and muscular systems (Haff and Dumke, 2012). The values that are thought to represent this functionality are expired gases resulting in measurement criteria of maximal oxygen consumption, which is a product of cardiac output (function of heart rate and stroke volume) and arterial-venous oxygen difference.

Maximal oxygen consumption is commonly referred to as VO2 max and is defined as the highest rate of oxygen transport that can be achieved by the athlete at maximal physical exertion. Theoretically, the more oxygen that an athlete can use during moderate to vigorous exercise, the more energy (ATP) the athlete can produce, resulting in longer cardiovascular endurance.

There are several laboratory and field tests that can be used to measure VO2 max. Maximal tests include direct measurement of expired gases and ventilation, which can be very strenuous and costly. Other methods for obtaining VO2 max are submaximal tests that can be performed in either a laboratory with a treadmill or on the field using equations to predict VO2 max.

For instance, the one-mile fitness walking test, or the step test are rather inexpensive methods that are fairly accurate at predicting VO2 max.

The Cooper 1.5-mile run/walk test is commonly used to estimate VO2 max because it is classified as a maximal test. Although walking is allowed during the test, the goal is to complete the 1.5 miles (2.41 km) as quickly as possible. The faster the athlete can complete the 1.5 miles (2.41 km), the higher their VO2 max is estimated to be. Using the following regression equation, the VO2 max can be calculated for a female or male athlete, respectively. The athlete should be assessed for their height and weight, as they are variables that will be needed to insert into the respective formula. The athlete should be allowed to warm up for approximately 10 minutes. The athlete is then instructed to run or walk the 1.5 miles (2.41 km) as fast as they can. The only equipment needed for this test is a stopwatch. The outcome observed for this assessment is the time it takes the athlete to complete the 1.5 miles (2.41 km). Once their time has been obtained, insert into the appropriate equation. A note on the following equations is that they have been shown to have a high correlation of *r* = 0.90 with maximal testing and a low standard error of the estimate (Haff and Dumke, 2012).

Equations:

Men: VO2 max (ml . kg^{-1} . min^{-1}) = 91.736 – (0.1656 X body mass [kg]) – (2.767 X 1.5-mile run time in minutes)

Women: VO2 max (ml . kg^{-1} . min^{-1}) = 88.020 – (0.1656 X body mass [kg]) – (2.767 X 1.5-mile run time in minutes)

Reaction Time

Another factor that plays a role in sports performance is the athlete's reaction time. This variable can be extremely important in determining success in sports. For instance, the reaction time of a quarterback throwing the ball before getting tackled, a baseball player trying to steal a base, a basketball player getting a rebound, a tennis player hitting a volley, and a soccer goalie blocking a goal can ultimately make the difference between winning and losing.

Reaction time is quantified as the time interval that elapses between the appearance of a stimulus and the athlete's time to respond to the stimulus. Several reaction time assessments have recently been developed. A few measures that are currently being used by major league baseball (MLB) players, professional football players in the national football league (NFL), and Australian football players (AFL) are the following: the reaction time ruler test, light board reaction timers, the SVT reaction test, and the Batak reaction board test.

The reaction time ruler test is relatively simple. The only equipment needed is a 1-meter-long ruler and a timer. It uses the properties of gravity to determine the amount of time it takes the athlete to respond to the dropping of an object by measuring the distance the object travelled before being caught. It is important to note that this is a good test for assessing eye-hand coordination and may be particularly relevant to tennis. Please see www.topendsports.com for specifics on the procedures, adaptations of the test, as well as products that have been developed such as reaction stick timers in an effort to more accurately assess reaction time.

The light board reaction timer test is another assessment that can be used to quantify hand-eye quickness and reaction time. It has been used in the sport of boxing as part of the SPARQ rating system for many years. The equipment required is a Bosu ball and a light board, which can be very costly. The protocol includes having the athlete stand on top of the Bosu and try to touch as many lighted areas on the board as possible. The outcome is total number of lights touched out of 90. For more specifics on this test, please refer to SPARQ rating system and www.topendsports.com.

The Batak reaction board test is a similar test to the light board reaction timer test, although there is no Bosu involved. It seems to have evolved from the basic concept of having a light board. The Batak reaction test has been designed to be commercially available. It consists of having light buttons that are randomly lit. The goal is for the athlete to touch as many of the lighted areas within a specified time of 30 seconds or 60 seconds. The outcome is the number of lights touched within either 30 or 60 seconds. For adaptations of the Batak, please refer to www.topendsports.com

The SVT reaction test was developed by SVT engineers to assess reaction time and eye-hand coordination for Australian football players. It is a grid/timer that has 4 rows of 8 lights, resulting in a total of 32 lights. Similar to other reaction tests, the athletes are instructed to touch as many as randomly lighted areas on the grid within 30 seconds. The outcome is the number of grids they touch within the 30-second time limit. For more specifics on this test, please refer to www.topendsports.com.

Agility

Agility is the ability to change direction as quickly as possible. There are many drills that are available to test as well as to train this factor. Currently, the NBA quantifies agility through the assessment of the following five drills: the lane agility drill, shuttle run, ¾ court sprint, the standing vertical leap, and the max vertical leap.

Also note that in their agility testing, there are actually several factors being assessed…

Question: can you guess what they are?

1. Agility drill = agility
2. Shuttle run = anaerobic power and speed
3. ¾ sprint = anaerobic power and speed
4. Standing vertical leap = anaerobic power
5. Max vertical leap = anaerobic power

Batteries of tests may include several KPIs, as such, it is important to understand what is actually being measured in order to make more accurate predictions of sports performance.

Another major assessment for agility that is used in the NFL combine is the 5-10-5 agility drill also recognized as the pro agility shuttle. The only equipment needed is a stopwatch and cones. The protocol includes having the athlete start with their hand touching the ground at the 5-yard line on the mark, they should turn 90 degrees to the right and sprint to the 10-yard line (a total of 5 yards, 4.57 m) as fast as they can and touch that line, turn back and sprint 10 yards (9.14 m) in the other direction, and finally turn back and sprint the final 5 yards (4.57 m) to the starting point. Starting sides should be alternated when testing, and time to completion is the outcome for this assessment of agility.

The following variables are considered factors that play a role in sports performance; however, they have been difficult to assess accurately. Speed is usually assessed through sprinting as a measure of anaerobic power, while coordination is sometimes included in reaction time assessments. Further research and development of measures are needed in the field to accurately quantify and distinguish where factors do not confound each other. Currently, researchers have been investigating constructs that may be responsible for the level of coordination that an athlete displays. For instance, depth perception (Howard-Dolman Apparatus), or how well an athlete's eyes fixate on an object and how quick their eyes can accommodate to distances (Saladin Near Point Balance Card), as well as how timing is affected by visual coordination or lack thereof through the use of eye-tracking devices.

Finally, this module included KPIs that are commonly assessed in professional sports, still this is not an exhaustive list, but an introductory module into the fundamental assessments that a sports scientist working in the pro sports industry captures in their daily work. Also, keep in mind that KPIs that are sports specific are recommended to also be quantified for a comprehensive assessment of the athlete.

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