Module 1. Science of Movement, Anatomy and Physiology

A successful sports scientist must understand the basics of science of movement, anatomy, and physiology as these are fundamental to obtaining a more comprehensive knowledge of what it means to be an athlete. Let us start by answering the question: What is an athlete? We can think of an athlete as a person who is skilled at a sport, trains, and possesses physical attributes such as muscular strength, power, endurance, speed, and agility, to name a few.

The objective of this module is to help you, as a sports scientist, understand the human body and how its machinery functions during athletic events in order to comprehend how performance is affected by physiology. This introductory module will open your eyes to new ways of thinking about number crunching and sports analytics. Knowledge of the main physiological mechanisms will make you a more competitive and insightful sports scientist.

Let us review the basic bone structure and anatomical information you should be aware of. The human body is made up of 206 bones and more than 430 skeletal muscles. The topic of anatomy alone should take up several books to do it justice. We will cover the part of human anatomy and physiology most relevant to sports performance.

The study of bones is called osteology. Osteologists dedicate their lives to understanding how bones function. Bones are responsible for providing constant renewal of red and white blood cells, and are vital not only to our organs, but to gaining a competitive edge in sports performance. There are many types of bones: long bones, short bones, flat bones, irregular bones, and sesamoid bones. Long bones are associated with greater movement due to the lever length, compared to short bones which have limited mobility, but are known to be stronger. Please refer to the table below for examples of each type of bone.

Table 1: Types of bones

Type of bone	Example of bone
Long bones	Femur, Humerus, Tibia
Short bones	Tarsals of the foot, Carpals of the hand and wrist Flat bones Scapula, Sternum, Cranium
Irregular bones	Vertebrae, Sacrum, Mandible

Sesamoid bones	Kneecap, there are four sesamoid bones in the hand, there are two sesamoid bones in the foot

Source: adapted from Martin et al. (2016)

The musculoskeletal system is integral to human movement, as it consists of ligaments that connect bone to bone and tendons that connect muscles to bone. Consequently, when the muscle pulls on the bone, motion occurs. Depending on the method of classification or grouping, estimates of the number of muscles in the body range between 430 to over 900. In fact, each skeletal muscle is considered an organ that contains muscle tissue, connective tissue, nerves, and blood vessels. Much of the debate is a matter of definition in terms of how the muscles are quantified.

Like bones, muscles may be classified by type: smooth muscle is found in the blood vessels and organs, cardiac muscle is found in the heart, and skeletal muscle is abundant throughout the human body and is responsible for our daily movement.

Upper body muscles and muscle groups you should become familiar with include the latissimus dorsi, trapezius, deltoids, rotator cuff, pectorals, biceps, triceps, and brachioradialis. Midsection muscles involved in sports performance include the rectus abdominus, external and internal obliques, and the transversus abdominis. Lower body muscles vital for many sports include the quadriceps, hamstrings, gluteus (maximus, minimus, medius), gastrocnemius, and the soleus. Please refer to the table below for the locations of these muscles and their function in sports.

Table 2: Muscles in action in sport performance

Name of Muscle	Location of Muscle	Function in Sport
Upper Body Muscles		
Latissimus dorsi	located in the posterior part of the body, largest muscle group in the upper body, also called the back	involved in extension and adduction of the shoulder as well as pulling motions; relevant for all sports
Rhomboids	located in the upper back underneath the trapezius and consists of two muscles; rhomboid major and minor	involved in retraction of shoulder blades relevant for all sports
Trapezius	located above and superficial to rhomboids extends from shoulders to neck muscles	involved in distributing loads away from the neck and keeping the shoulders stabilized
Deltoids	commonly referred to as the shoulders	involved in throwing motions used extensively in overhead athletes
Rotator Cuff	located in the shoulder area deep under the deltoids, muscles that hold the shoulder in place	involved in throwing motions; quarterbacks, pitchers, and tennis players when serving
Pectorals	commonly referred to as the chest includes pectoralis major and minor	involved in chest press strength, and abduction of the shoulder and pushing movements
Biceps	located in anterior part of the arm and called biceps because of the two heads of the muscle	involved in swinging motion; tennis players forehand and baseball swings; also involved in bending of the elbow and for picking up motions
Triceps	located in posterior part of the arm and called triceps because of the three heads of the muscle	extension of elbow; used to straighten the elbow; used in stiff-arm movement in football players
Brachioradialis and Pronator Teres	forearm muscles	utilized in sports using the wrist
Core and Midsection Muscles		
Rectus Abdominus	located in the anterior part of the body under the abdomen	utilized for flexion of the spine and core stabilization; relevant for all sports
External Obliques	located above and superficial to the internal obliques on each side of the trunk	utilized for sideways bending and rotation of the torso; integral for tennis strokes
Internal Obliques	located underneath the external abdominal oblique on each side of the trunk	utilized for flexion of the spine, sideways bending, trunk rotation and compression of the abdomen; relevant for all sports
Transversus Abdominis	located in the deepest layer of abdominal muscles that wraps around the torso	utilized for respiration and core stabilization; relevant for all sports
Lower Body Muscles		
Quadriceps	located in anterior part of thigh consisting of four muscles	responsible for extension of the knee; major source of strength for soccer players; relevant for all sports
Hamstrings	located in posterior part of thigh consisting of three muscles	responsible for flexion and bending of the knee; relevant for all sports
Gluteus Maximus, Gluteus Medius, and Gluteus Minimus	located in the area usually called the buttocks	utilized in explosive first step movements; integral for lower body strength and power
Gastrocnemius	located in the lower leg area and typically referred to as part of the calf muscle	utilized in jumping and tip-toe motions including being on the ball of your feet
Soleus	located in the lower leg area and typically referred to as part of the calf muscle	utilized in jumping and tip-toe motions including being on the ball of your feet

Source: Martin et al., 2016.

Many of you have heard of fast twitch and slow twitch muscle fibres. Most people are only aware of two fibre types, fast and slow, or white and red. However, it is much more accurate to say that there are hybrid fibre types that lie within the spectrum of Type I and Type II muscle fibres. More recently, the scientific field revealed three distinct categories of muscle fibres. These are Type I, Type IIa, and Type IIx muscle fibres. Type I fibres are commonly referred to as slow-twitch, while both Type IIa and Type IIx are recognized as fast-twitch muscle fibres.

To facilitate understanding, we will focus on the differences between Type I and Type II because they are inherently different as they relate to the following characteristics: ability to utilize oxygen and glycogen as determined by aerobic enzyme content, myoglobin content, capillary density, and mitochondria size and density.

Typically, slow-twitch muscle fibres tend to be high in all the criteria mentioned above. In comparison, fast-twitch muscle fibres tend to be low in these characteristics, while having greater nerve conduction velocity, speed of muscle contractility, anaerobic enzyme content, and power output. Fast twitch fibres are known to have high glycolytic activity, meaning they utilise glycogen (the storage form of glucose, which many call sugar) at high levels, whereas slow-twitch muscle fibres rely on their oxidative capacity. Please refer to the table below for additional muscle fibre type characteristics.

Table 3: Characteristics of muscle size

Characteristics	Type I	Type IIa	Type IIx
Motor neuron size	Small	Large	Large
Nerve conduction velocity	Slow	Fast	Fast
Contraction speed	Slow	Fast	Fast
Relaxation speed	Slow	Fast	Fast
Fatigue resistance	High	Intermediate/Low	Low
Force production	Low	Intermediate	High
Power output	Low	Intermediate/High	High
Endurance	High	Intermediate/Low	Low
Aerobic enzyme content	High	Intermediate/Low	Low
Anaerobic enzyme content	Low	High	High
Capillary density	High	Intermediate	Low
Myoglobin content	High	Low	Low
Mitochondria size/density	High	Intermediate	Low
Fibre diameter	Small	Intermediate	Large
Colour	Red	White/Red	White

Source: adapted from Baechle and Earle, 2008.

It is evident that anatomy and physiology play a major role in sports performance. A sprinter may benefit from a greater number of fast-twitch muscle fibres, whereas a long-distance runner will benefit much more from having a greater distribution of slow-twitch muscle fibres. Refer to the table below for Type I and Type II muscle fibre contribution in a variety of sports.

Table 4: Muscle fibre types and sports

100-meter sprint	Low	High
800-meter sprint	High	High
Marathon	High	Low
Soccer	High	High
American Football Wide Receiver and Linemen	Low	High
Basketball	Low	High
Baseball Pitcher	Low	High
Tennis	High	High

Source: adapted from Baechle and Earle, 2008.

In addition to the controversy over the number of muscle fibre types, there also remains the question whether one can train and modify one's own fibre type through conditioning. Recent studies have shown that enzymes that would otherwise be dormant are activated through physical training, implying that there is a possibility of changing the fibre type to a certain degree.

Now that we have the basics of the skeletal and muscular system, let us consider the physiology of sports performance. First, we must realize that human metabolism includes both anabolic and catabolic processes that are ongoing in our bodies. Anabolic processes involve the synthesis of larger molecules from smaller molecules. Conversely, catabolic processes involve the breakdown of larger molecules into smaller ones and are associated with the release of energy. Energy released in a biological reaction is quantified by the amount of heat that is generated. The amount of heat required to raise one kilogram of water one degree Celsius is called a kilocalorie. This corresponds to the energy found in food that is broken down within our bodies and stored in the form of adenosine triphosphate (ATP).

In the body, energy systems are responsible for providing the ATP (energy) that is utilised under varying intensities and durations of sport performance. There are three main energy systems at play during sports performance. They are the phosphagen (ATP-PCr) system, the glycolytic system, and the oxidative phosphorylation system. All three systems are constantly at work and interacting with each other, functioning on some level, as they are not "all or nothing" systems. The predominance of one system is largely determined by the intensity and duration of the sporting activity, as well as the substrate (food source) that the athlete has consumed. Substrate utilisation is a fancy term for the food that is being consumed by the athlete. Correspondingly, these three energy systems are also sometimes referred to as bioenergetics systems.

The athlete's ability to perform is based on his or her muscles' capacity to function and depends on the oxygen or glucose (substrate) availability. What does this mean? Well, if an athlete is sprinting, muscles within the body do not necessarily have the time required to be able to utilise oxygen, as a body at rest does. This causes the body to shift into an anaerobic state in which it can extract energy in the form of ATP, without the use of oxygen. However, when the human machine is running at a slower pace, the standard metabolic processes that utilise oxygen are allowed to occur in the mitochondria (the engine of the cell). Some might say that the human body is inherently intelligent and can be compared to a computer, in that after the program is built and the algorithm established, it knows what to do on its own.

To simplify, the three energy systems will be referred to as the phosphagen, glycolytic, and oxidative systems. These systems produce ATP and replenish ATP stores within the human body. The body naturally stores sufficient ATP for basic cellular functions, not the amount necessary for sports. The phosphagen system utilises an enzyme, creatine kinase, to maintain ATP levels during intense, explosive movements of short duration, allowing for the release of one mole of ATP or the equivalent of 0.6 kilocalories. The phosphagen system is heavily involved in sports that consist of high intensity, short-term explosive movements. This system is used in all sports at the point of initiation of activity—at the shift from sedentary to active.

The glycolytic system is responsible for controlling glycolysis (breakdown of glycogen) for energy production, as well as the onset of lactate formation. Glycolysis is the term for the processes that break down glycogen stored in the muscles to glucose, ultimately yielding ATP. Remarkably, intensity and duration of the sport also dictates the type of glycolysis that occurs. There are two possible pathways: The shorter path, termed anaerobic (fast) glycolysis, consists of fewer steps that lead to lactate; the other path, aerobic (slow) glycolysis, has a longer trajectory and yields two to three moles of ATP or the equivalent of 1.2 to 1.8 kilocalories. Aerobic glycolysis is a slower process. It requires sufficient quantities of oxygen to operate, compared to anaerobic glycolysis which can function with limited amounts of oxygen.

Finally, the oxidative system is responsible for breaking down glycogen, fat, and protein. It is also responsible for producing ATP when the body is at rest or during long-lasting, low-intensity sporting activities. It is a commonly held belief that, when training at low intensity, the body utilises more fat than other sources (carbohydrates or protein) of energy. This concept is the result of a simplified interpretation of this third system.

The oxidative system's primary source of fuel is fat, since it initiates the release of triglycerides from fat cells. This leads to the roaming of free fatty acids in the blood, which are transported to the muscle fibres for oxidation (burned for energy). The breakdown of fat to glucose is called lipolysis and yields between thirty-six and forty moles of ATP, or the equivalent of 21.6 to 24 kilocalories.

Additionally, this system is able to oxidise protein, however, protein is not its favoured source of fuel. The mechanism of breaking down protein into energy is less than efficient. Proteolysis requires several steps to break down protein into amino acids, and eventually converts the products to glucose through another process called gluconeogenesis. A greater span of time is needed to synthesize ATP. Therefore, fat and carbohydrate are the preferred fuels for sport because they yield energy at a much faster rate over longer periods. Please refer to the table below for the rate and capacity of ATP production for each energy system.

Table 5: Rate/capacity of Adenosine Triphosphate (ATP)

Energy System	Rate of ATP production	Capacity of ATP production
Phosphagen	1	5
Fast Glycolysis	2	4
Slow Glycolysis	3	3
Oxidation of Carbohydrates	4	2
Oxidation of Fats and Proteins	5	1

Note: 1 = fastest/greatest; 5 = slowest/least

Source: adapted from Baechle and Earle, 2008.

The athlete’s predominant energy system differs not only by sport, but also by player position or style of play within a particular sport. For instance, when a tennis player sprints to hit a forehand, a basketball player jumps explosively to slam dunk, a baseball player sprints to get on base, a quarterback throws the football, or a striker shoots to score a goal, their bodies are using the phosphagen system as the primary energy mechanism. If, on the other hand, a wide receiver is sprinting down the field for more than six seconds, his body has shifted from using the phosphagen system to a hybrid state consisting of both the phosphagen and glycolytic (anaerobic glycolysis) systems.

A soccer midfielder running non-stop, back and forth at a fast pace for the duration of one to two minutes, is in a true state of anaerobic glycolysis. If the soccer player were to continue running for a longer period of time, ranging from two to three minutes, they are likely to be in a hybrid state of fast glycolysis and oxidative phosphorylation. Finally, a long-distance runner who runs for prolonged periods of time at a slower rate is using the oxidative system as the primary mechanism for producing ATP. Refer to the table below for the ranges of intensity and duration typical of each energy system.

Table 6: Primary Energy System Duration and Intensity

Duration	Intensity	Primary Energy System
0-6 seconds	Extremely High	Phosphagen
6-30 seconds 2 minutes High	Very High Fast Glycolysis	Phosphagen and Fast Glycolysis 30 seconds to
2-3 minutes	Moderate	Fast Glycolysis and Oxidative System
>3 minutes	Low	Oxidative System

Source: adapted from Baechle and Earle, 2008.

In summary, the phosphagen energy system primarily supplies ATP for high-intensity activities of short duration. The glycolytic system is associated with moderate- to high-intensity activities of short to medium duration. And the oxidative system is the primary system at work during low-intensity activities of long duration.

Table 7: Limiting factors for energy systems

Degree of Exercise	Creatine Phosphate	Muscle Glycogen	Liver Glycogen	Fat Stores	Lower pH
Light (Marathon)	1	5	4-5	2-3	1
Moderate (1,500 m run)	1-2	3	2	1-2	2-3
Heavy (400 m run)	3	3	1	1	4-5
Very intense (discus)	2-3	1	1	1	1
Very intense and Repetitive Motions	4-5	4-5	1-2	1-2	4-5

Source: own source.

The table above describes the limiting factors of the bioenergetics systems. It shows how athletes, depending on the sport they play, involuntarily utilise bioenergetic systems. If we take a look at the discus thrower, it is important for their performance to have enough ATP and creatine phosphate in order to throw the discus in a powerful manner. On the other hand, if we take a look at marathon runners, they are much more limited by the amounts of glycogen (large amounts of glucose grouped together) stored in the muscles and liver because of its role in glycolysis and oxidative phosphorylation. Thereby, if they are limited in muscle or liver glycogen, their performance will be hindered greatly.

The table below describes the primary system that will be utilised by percent maximum power and duration of exercise (sport). With this information, we can learn to train our bodies to utilise different systems. For example, if you are an athlete that wants to improve utilisation of the phosphagen system, then you would train one time (sprint) at 90 percent intensity for five seconds in duration at a work to rest ratio of one to twenty, meaning you would rest (5 × 20) 100 seconds, or a minute forty. If, however, you would want to improve your cardiorespiratory endurance, you would train at 20–30 percent for longer duration at a work to rest ratio of one to three at most.

Table 8: Athletic training and energy systems

Percent maximum	Primary system utilised	Typical exercise time	Range of Work-to-rest period ratios
90-100	Phosphagen	5-10 seconds	1:12 to 1:20
75-90	Fast Glycolysis	15-30 seconds	1:3 to 1:5
30-75	Fast Glycolysis and Oxidative	1-3 minutes	1:3 to 1:4
20-30	Oxidative	> 3 minutes	1:1 to 1:3

Source: adapted from Baechle and Earle, 2008.

The table below details physiological markers of performance outcomes. It is well documented in the literature that testosterone, growth hormone, and IGF-1 are strongly related to muscle mass development and maintenance as well as bone density. Lactate levels are commonly used to assess whether the athlete is fatigued. Training that requires high level of technique or skill should not be performed, since coordination is significantly decreased and risk of injury is increased when high amounts of lactate are present in the blood. Additionally, the hormone cortisol is known to be extremely elevated when an athlete is overtraining causing inflammation and stress in the body, which chronically, may lead to injury.

Table 9: Physiological markers of athletic performance

Physiological Performance Outcomes	Markers
Muscle mass development and maintenance	Testosterone, growth hormone, IGF-1
Bone density	Testosterone, estrogen
Fatigue	Lactate levels
Overtraining	Cortisol
Cellular aging	Telomere length and Methylome assessment
Heart function	Heart rate, stroke volume, heart rate variability, cardiac output, and blood pressure
Aerobic threshold	Aerobic enzyme content, VO_2 max
Anaerobic threshold	Respiratory rate

Source: adapted from Martin, 2016.

More recently, there has been extensive research on delaying ageing. Telomeres are located at the end of our chromosomes within our DNA. You may ask: Why is this relevant to sport? Professional athletes are interested in prolonging their athletic careers and, since telomeres have been shown to be strongly related to physical ageing, this is a relevant marker of having an extended athletic career. Many studies have already shown that longer telomeres are associated with healthier and longer lifespans in both animal and human models. A newer method of assessing ageing is Methylome analysis. It has been shown to have an even stronger correlation to physical ageing than telomere length. It is now recognized as a measure of biological age and can have major implications for injury prevention and the extension of athletic careers.

Heart function is important to athletic performance. The ability of the heart to distribute blood and oxygen to the muscles is fundamental for optimal performance. Heart rate is commonly used to assess intensity. For instance, many strength and conditioning experts utilise heart rate zones as indicators of exercise intensity (training). It is significant to assess heart functionality by not only measuring heart rate, but also stroke volume, heart rate variability, and cardiac output.

Anaerobic and aerobic thresholds are also essential to assess. Based on the sport, it is recommended that respiratory rate and VO2 max be examined. Respiratory rate assessment is especially relevant for sprinters, whereas VO2 max would be most appropriate for marathoners.

In order to obtain an accurate predictive model of sport performance, it is important to include cardiovascular physiological measures, such as heart rate, resting heart rate, heart rate variability, stoke volume, cardiac output, and blood pressure. It is also critical to include measures of lactate threshold, insulin and glucose levels, a vision assessment, and markers of cellular ageing. Physiological variables reflect the internal state of the body and yield a picture of the body's engine and how and why it runs the way it does.

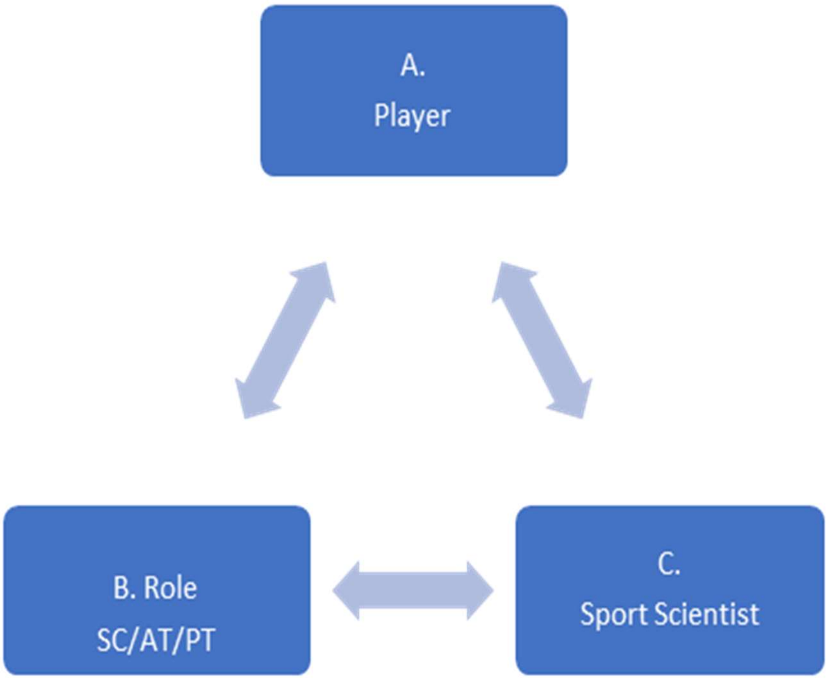
Now, you can begin to see the whole picture and conduct more relevant exploratory analyses. Knowledge of anatomy and physiology will make you a more marketable and competitive sports data analyst against those who only see the numbers, whether those numbers come from a laboratory setting, training facility, or wearable technology in the field.

Fundamentals of Sports Science Data Collection

Professional athletes are always seeking to gain a competitive edge. A slight improvement in any aspect of sports performance can lead to a significant difference in performance outcomes. It has been well-documented in the literature that different areas of sports performance such as athletic training, physical therapy, strength and conditioning, nutrition, and sports psychology function independent of one another without sharing resources and information within professional organizations. This is where the role of the sports scientist comes in, as they can be the connecting link between these distinctive areas of expertise, as their proficiency should be to have a general understanding of all the areas and understand which outcome or dependent variables should be quantified to provide a meaningful metric that is relevant to the athlete's performance.

For the data and analytics to be absorbed by the support staff, there has to be a productive relationship between the athlete, support staff, and the sports scientist. Furthermore, they should have a good understanding of the Key Performance Indicators (KPIs) relevant to the athlete's performance. Moreover, the sports scientist should be directly in communication with the professional athletes and the sports performance experts from different areas, as shown in the figure below.

Figure 1: Sports Scientist Role Diagram



Source: Martin, 2019, p. 37

Role is a placeholder for any sport performance expert such as strength coach, athletic trainer, physical therapist, nutritionist, or sport psychologist to exemplify the direct line of communication with a) player, b) role, and c) sport scientist.

In many instances, due to teams being short-staffed or the lack of the role of a sports scientist, teams assign one of the subject-matter experts to try to carry out the duties of a sports scientist. However, ideally, there should be a sports scientist staff with expertise to have the ability to be innovative, ask pertinent research questions, and identify KPIs that can help maximise athletic performance.

The role of the sports scientist consists of knowledge on how to collect, analyse, interpret, present, and secure the data. Furthermore, sports scientists in professional sports teams should have the ability to produce distinct reports to players, coaches, and front office management (general manager, assistant general manager, analytics staff).

The sports scientist's first initiative should be to ask questions such as the following:

- What are the KPIs that would help the athlete's performance?
- What meaningful implication will this data have?
- How should data be collected?
- What data is valuable and simple to measure?
- How to choose a technology to measure the variables?

- How long will it take to collect this data?
- How to request consent from the athlete?
- Where is the data going to be stored?
- Who will have access to the data?
- Is the data stored in a secure location?

Identification of Data and Key Performance Indicators

The sports scientist should then concentrate on identifying KPIs and the type of load to be quantified. The terms **load** and **training load** (TL) are typically applied interchangeably and sub-classified as either internal load or external load.

Internal load represents psychological variables such as confidence and anxiety and physiological KPIs such as heart rate variability, lactate threshold, glucose and insulin levels, etc.

External load is characterized by physical, biomechanical, behavioural and environmental KPIs.

It is critical to distinguish between internal load and external load and how they should be quantified. For instance, many of the KPIs of external loads such as power output, acceleration, and speed are derived from wearable technology such as accelerometers, gyroscopes, magnetometers, and global positioning systems (GPS). Whereas, KPIs of internal loads such as lactate threshold and rate of perceived exertion (RPE) are obtained through either biomarker assessments or self-reported questionnaires.

The practical implication of measuring TL is to help the sports scientist and training staff better help the athlete by establishing appropriate TL thresholds. This will also allow you to gain insights into strengths and weaknesses of the athlete in efforts to reduce the risk of injury, examine what works for the athlete, and help them to continue to improve their performance.

Based on the sport, position, and player body composition, some variables and KPIs may be more relevant than others. See the table below for a list of variables and KPIs related to sports performance.

Table 10: Measurement model of sports

Table 1. *A Measurement Model for Sports*

Physiological	Physical	Psychological	Behavioral	Environmental
Blood pressure	Agility	Anxiety	Nutrition	Built environment
Glucose and insulin	Anaerobic power	Competitiveness	Sleep	Social support groups (Coaches, Parents, Peers)
Heart rate variability	Balance	Confidence	Substance use	Socioeconomic status
Lactate threshold	Body composition	Depression		
Methylome	Cardiorespiratory endurance	Impulsiveness		
Previous injuries	Coordination ability	Intellect of sport		
Respiratory rate	Flexibility	Motivation		
Resting heart rate	Muscular endurance	Narcissism		
Telomere length	Muscular power	Perfectionism		
Vision	Muscular strength	Resiliency		
VO_2max	Reaction time	Self-efficacy		
	Sport-specific skills	Self-esteem		
		Vigor		

Source: Martin L[6]

Source: Martin, 2019, p. 37.

In the following modules, we will cover and detail some of the most important KPIs listed in the table above, however, it is essential that you become knowledgeable in the sport that you are working in as well as the needs of the athletes not only in the sport, but those required of their position in order to quantify the KPIs that will be most beneficial to the athlete's performance and health.

After choosing the KPIs of interest, the sports scientist is responsible for choosing the appropriate measurement, assessments, and form of evaluation. Therefore, it is fundamental for sports scientists to be able to distinguish between measurement, assessment, and evaluation. Sports scientists should know that measurement is the assignment of numbers to quantify a characteristic being assessed, while an assessment or test is a tool to make the measurement, and evaluation is the judgment on the quality of the assessment of the measurement.

Furthermore, it is a given that sports scientists are the vetters of the product companies and technologies and as such are expected to know how to validate the instrument of measurement as well as establish reliability. Validity is the term used to describe whether the technology or instrument measures what it is set out to measure. In the pro sports industry, there are many products of wearable technology being marketed to the training staff daily. Therefore, it is critical for the sports scientist to assess whether the technology is valid and measures what it is purported to measure or not. As such, it is important to be able to evaluate how valid these technologies and instruments are by validating the technology or instrument against a gold-standard, in order to establish criterion validity. Once the instrument or technology has been chosen and validated, the concentration should shift from the instrument or technology to the data output. It is ideal to obtain the raw data files as it can also help the sports scientist understand the underlying algorithm of the formulated commercialised metrics being offered by the equipment manufacturers. As such, Course 2 has been dedicated to wearable technologies. In fact, the gold standards for physical activity and sleep will be discussed, as the fundamental aspects of sports revolve around daily activity or lack of thereof.

References

Baechle, T. R. and Earle, R. W. (2008). *Essentials of Strength Training and Conditioning. Third Edition*. Human Kinetics.

Martin, L. (2016). Sports performance measurement and analytics: The science of assessing performance, predicting future outcomes, interpreting statistical models, and evaluating the market value of athletes. FT Press.

Martin, L. (2019). Sports Science Data Protocol. *Sports and Exercise Medicine Open Journal, 5*(2), 36-41. http://dx.doi.org/10.17140/SEMOJ-5-174