Module 2. Data management

Unit 2.1 Background

Lluis Til

For the team staff, good health and athlete performance are, two interrelated and highly influential objectives. At the same time, they are the responsibility of the team physician and the coaching team, including all the members of the coaching team who interact with the athletes, the team and the sports organization.

Therefore, fulfilling these roles requires specific knowledge and skills. Performing this work close to the athletes facilitates the acquisition of knowledge of the particular circumstances surrounding competitive sport in general and the team in particular. This allows for decision-making based on the factors involved in each sports phenomenon.

Management of specific situations must be carried out according to medical criteria which are based on the following:

- Respect for the patient, particularly in the relationship that the professional establishes with them, which must be egalitarian in order to avoid authoritarian or paternalistic attitudes.
- The physician should not only diagnose but also educate the patient, motivating them to actively identify and solve their health problems, without any type of imposition.
- The physician should be a communicator in the sense that they should know how to reach and talk to the patient, so as to foster their active participation in decisions related to the injury process.
- Respect for the accepted and current medical practice: the athlete, like any patient, has the right to receive the best possible treatment, based on evidence and experience. The patient must be protected from unproven miracle therapies and procedures, especially injured athletes who are particularly vulnerable.
- Respect for the ethics of human relationships and the ethics that should guide every medical act. This includes maintaining absolute confidentiality, which is especially difficult regarding the health of famous individuals.
- Respect for efficiency, assessing the cost-benefit ratio and opting for the option considered optimal from the point of view of the pathology, the player's psychosocial well-being and economic aspects.

Team physicians and all those involved in the health care of athletes are, in a way, victims of the success of modern medicine, as patients find it difficult to come to terms with injury and its possible consequences. Sometimes, the pressure exerted on athletes leads them to hold the medical staff accountable for certain circumstances. For example, when given the time required to deal with an injury process, sports objectives are not met.

2.1.1 The Medical History and the Clinical Course

The medical history is the document that reflects the relevant aspects of the medical act itself. It is a written or verbal account of the patient's medical state, and it can be obtained through the patient's own account or that of third parties involved. It is up to the practitioner to decide what to include in the history and how to narrate it. The practitioner's name should be recorded in every part of the medical history, since any anonymous record will result in an incomplete medical history. Healthcare institutions and clinical departments of sports organisations that make use of them are responsible for doing so through paper or devices that enable the recording, saving and use of the data and documentation that is part of the medical history.

Aspects of an athlete's medical history:

a. Details of the patient's affiliation, which make it possible to locate them (address, telephone, e-mail) and those of the patient's relatives of their choice who should be notified of any eventualities.
b. Documents signed by the patient and the physician stating that the athlete has been informed of the nature of the medical act, the need for medical recording and, if necessary, the way in which the analysis and management of the data will be carried out. Signed general consent forms do not authorise future management of the data recorded in the medical history if this has not been duly notified.
c. Initial sports medical examination:
    i. - Personal, family, sports and toxic background.
    ii. - Pathological history, allergies, previous admissions, surgeries, and history of injuries and concussions.
    iii. - Systemic examination by organs, with special attention to the cardiorespiratory system and the locomotor system. It is crucial to perform a peripheral and central neurovascular check-up, as well as tests of the sense organs.
    iv. - Vaccination history, nutritional and resting status.
    v. - Anthropometric exam.
    vi. - Resting electrocardiogram.
    vii. - Echocardiogram.
    viii. - Ergometry with stress electrocardiogram.
    ix. - Spirometry.
    x. - Other functional tests.
d. Biological monitoring data, clinical analyses, anthropometric evolutionary measurements and functional tests.
e. Pharmacological and supplementation records which may need to be consulted at any time in light of an anti-doping test. Regarding drugs, which should be administered by nurses, there has to be a prescription indicating and justifying their use, dosage, and the duration of and compliance with the treatment.
f. Records of each medical procedure, which must follow a temporal order, with a beginning, a clinical evolutionary course and an end. In each procedure it is advisable to check:

i. - Patient's data, reason for consultation and clinical examination
ii. - Initial judgement, including the differential diagnosis, diagnostic plan and initial therapeutic measures.
iii. - The diagnostic tests requested, as well as the images and reports, which must be adequately stored.
iv. - It is advisable that the diagnosis includes coding. In competitive sports, the Orchard Sports Injury Classification System (OSICS-10; goo.gl/4Zctpi) coding is widely used. It is a code recommended by UEFA, FIFA and IOC. In the OSICS code, each diagnostic procedure is coded by four letters: the first letter refers to the anatomical location of the injury or, if it is a medical condition, to its development or post-surgical condition; the second letter refers to the type of tissue, organ or system affected by the injury; the third and fourth letters are specific to each situation.
v. - The therapeutic plan, detailing recommendations, modifications to the physical activity plan, medication, orthoses or mechanical aids use, surgery (if indicated) and the rehabilitation plan, including the objectives to be achieved and the time needed to achieve them. On this basis, an approximate time prognosis can be made, which is particularly appreciated in some contexts or circumstances.
vi. - The developmental process or clinical course, which shall be daily, whenever this is deemed appropriate.
vii. - Physiotherapy and post-injury sports rehabilitation records. The therapeutic planning based on the objectives set and the monitoring of the plan should be recorded. These record,s and compliance with the plan make the effectiveness of the proposed plan evident These records are the responsibility of the physician who performs them. In intermediate and long-term processes, a sequential approach of objectives and a subdivision of the process into phases is advisable, with pre-established criteria that allow for a non-subjective justification of the progress or stagnation of the process.
viii. - The assessment, screening and functional tests used to monitor the process.
ix. - Discharge from competition, together with restrictions and recommendations typical of secondary prevention.
x. - Copies of the documents sent to insurance companies which signal the start and end of the process, as well as the follow-up documents which are often requested by insurance companies.
xi. - Evidence related to the injury mechanism, such as videos, should also be kept with the medical history so that it is easily accessible.

g. The follow-ups and records of other health professionals, which are not related to clinical processes per se. Thus, the medical history may contain separate sections for all of the following:
    i. - Nutrition: intolerance, recommendations, allergies and needs are recorded, as well as supplementation and monitoring of nutritional status, body structure and supplementation needs.

ii. - Podiatry: orthopaedic monitoring, including records of plantar footprint, static and dynamic; any orthosis needs and their characteristics.
iii. - Psychology: which requires special care regarding confidentiality issues.
iv. - Physiotherapy: including aspects related to the preparation of training sessions and matches, such as massages, bandages, stretching, management of discomfort and day-to-day activities. The record of physical actions aimed at recovery from post-workload fatigue is particularly interesting.
v. - Nursing: the specific processes should be recorded, especially those that refer to biological sampling, medication, parenteral therapy, skin and adnexal care, wound management and vaccination, among others.
vi. - Other professionals who occasionally take part in assisting the athlete should also be included in the medical history, where they can keep records of their activity in a coherent and orderly manner.

Access to medical histories and clinical documentation is reserved to the owners of the medical records, who are:

- The patient, as it is drafted for his or her benefit and concerns his or her health and privacy.
- The physician, as the intellectual and scientific author of the record, and leader of the medical team caring for the athlete.
- Each professional who records something in the medical history considers himself or herself the owner of the part in which he or she participates.

The health care institution or sports organisation cannot consider itself the owner of the contents of the medical history. The right to property, which must be respected, has to do with access to and availability and use of medical records, as well as obligations of confidentiality and their preservation.

2.1.2 Data Recording and Analysis

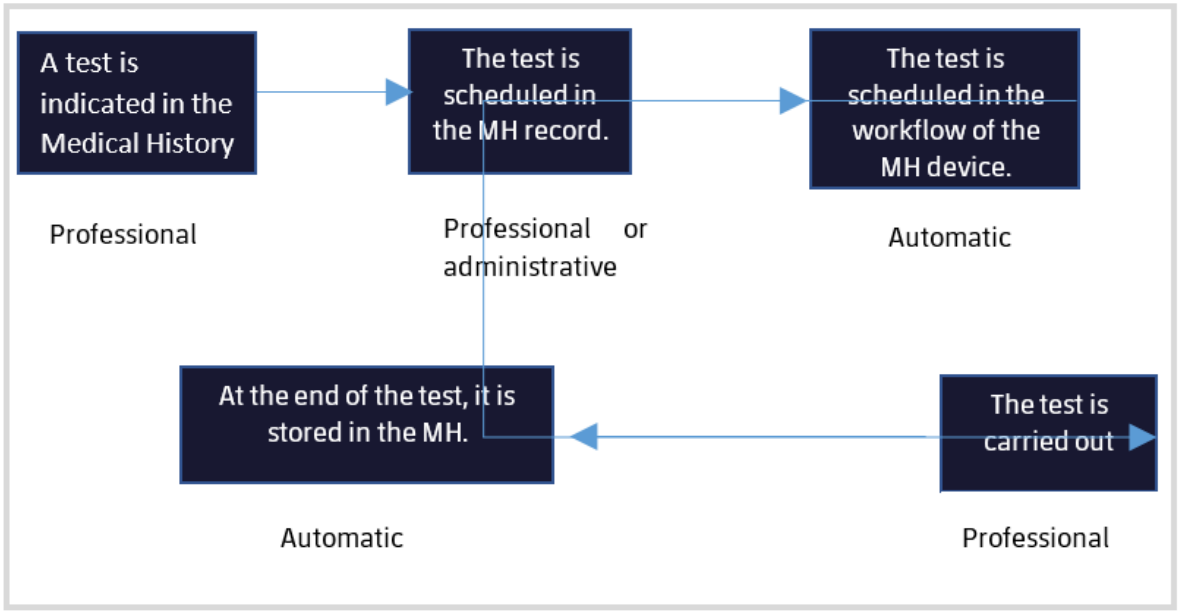
Data recording must be safely carried out. The possibility to do so electronically and consistently allows for the implementation of access authorisations and records traceability. This model must meet the security requirements laid down by regulations, ensuring records inviolability, data confidentiality and access traceability. At the same time, it should ideally allow for cross-sectional, longitudinal and transversal analyses. When considering team sports, some of the specific data should be analysed individually or as a whole. Probably, this is only possible through electronic records.

A planned medical history model consisting of parametric fields that are as closed-ended and as quantitative as possible, facilitates recording, minimises the risk of error and makes it possible to establish effective data management models. Data management can be automated, facilitating the generation of reports and dashboards, which allow for

quick situation analyses. An electronically-stored medical history facilitates the communication between all the professionals who have access to it in a secure and concrete way. In addition, it reduces interpretation misunderstanding typical of oral messages and prevents security risks typical of telephone communication or electronic systems (such as e-mail or WhatsApp), which are excessively used when it comes to discussing personal aspects of athletes.

Revising the medical history in retrospect, out of medical interest, for medical training purposes or for legal purposes is safer and more complete when confronted with the electronic medical history model. Information transfer from servers outside the medical history itself is particularly interesting but it requires the implementation of security protocols to make this communication reliable and not to provide any entry points that put the system at risk. If the communication protocols are not reliable enough, or if the system administrators do not guarantee such reliability, additional outside information that is considered relevant to the medical history should be stored, the image files should be copied and the original documents should be scanned and saved in .pdf formats.

Figure 1: Structure of Medical History



Source: Author's production.

The workflow proposed in the above figure is a working proposal for data and images generation and storage by the clinical department's own devices. It is recommended that clinical departments with analytical, testing and screening tools store the information obtained through these means in the medical history. This data and images transfer must be carried out automatically after the acquisition of the data by the device.

Digitisation of old medical records is a costly process, but it ensures that the recorded information is not lost or damaged, so that it can be consulted in the future

2.1.3 Confidentiality

Medical acts and the records derived from them are based on trust between the parties involved. In order to maintain trust, and as part of the ethical code that should guide professional conduct, secrecy is essential. Health issues are one of the most intimate spheres of any individual, so any communication regarding any of these issues should be specially authorised. Also, it must be ensured that records are sufficiently shielded, and that any breach of security access is traceable.

Currently, most professional athletes' contracts establish that, if an injury or any condition that may affect the athlete's performance occurs, coaches and team owners will receive information about the athlete's health status. However, it is always important to respect the individual and their rights, so it is advisable to talk to the athlete about their situation and options, to ensure that a therapeutic plan is in place before contacting those other parties. Of course, any external communication with the media about an athlete's health should be agreed on with the athlete and, if possible, with their managers and coaches. Advice from the communication department is usually very helpful in these situations. It is important to note that athletes may want other people to be informed of the process. This must be skilfully handled and knowing it is done at the request of the patient, and that those receiving the information will use it for the athlete's benefit. The physician should also work together with the other medical professionals involved in the process, as well as the physiotherapist, physical trainer and strength and conditioning coach to assess the player's rehabilitation and competitive release to promote the necessary conditions for the athlete to return to play. In this case, effective and specific communication is crucial. The medical history and the records themselves become a reliable communication tool provided that those involved have proper access to the system.

Data and images transfer is critical when the athlete is injured or cared for outside the usual environment. Such information must be encrypted to ensure confidentiality. Such processes are common in other medical disciplines, especially when seeking second opinions.

2.1.4 Specific Software

The use of registry systems in hospitals and other medical institutions has given rise to various registry models that allow for the management of schedules and clinical records, with greater adaptations and connectivity the greater the complexity of the processes and the procedures administered.

A team sports physician's record-keeping needs differ greatly from the usual clinical record-keeping systems, since records in clinical medicine are not as extensive and versatile as those in sports medicine. The ideal system to meet the specific needs of competitive sports should be compatible with the following elements:

- Other schedules apart from medical ones, such as competition and training schedules.

- They should be multilingual platforms encompassing many fields. Today, teams are not made up of same-nationality athletes. Registry platforms must take this into account in order not to lose reliability, especially when it comes to informed consent documents and subjective rating scales. It also could happen that athletes need to be cared for in other countries, and foreign professionals need access to this information.
- They should have access to coding systems commonly used in sports medicine (OSICS-10).
- New elements of assessment and measurement are frequently incorporated and they need to be comprised into the system. Connectivity is therefore essential.
- Each sports discipline has different needs and epidemiology;therefore, some areas of the system need to be bypassed or visualised according to those needs.
- The system must also record individual parameters that are not directly related to pathological conditions. These are those conditioning factors that may have an impact on the capacity to adapt to workloads, which is the basis of training and which can be used to register risk factors.
- The system should work across-platforms. Action is increasingly taken in proximity to the field of play and training grounds, and during trips. Systems compatible to smart devices enable accessibility, which in turn increases the number of records and the chances for data management.
- Data analyses that have to do with athlete's physical condition and their perform during training sessions are very useful in decision making. Having this data and analyses available immediately is crucial for the users' assessment of software systems.
- One of the best resources to work with are platforms located in cloud servers that operate with data stored by the user and that have enough security measures to guarantee confidentiality, although they foster certain dependency on such system.

Each organization has different and special needs and requirements, This has led clubs, federations and international institutions to develop their own platforms. In these cases, the lack of compatibility between these systems makes it impossible to compare results. To achieve this end, new registry systems must be set up. However, these organisations have a limited development capacity which, over time, hampers their evolution or requires a significant financial effort.

Purchasing licences for the use of off-the-shelf medical history registry and sports tracking systems requires a lower investment, but these systems are not easily customisable to satisfy their particular needs. In this case, it is advisable to ensure the security and confidentiality of the system and to try to make sure that the company providing for the software remains active and also provides for the necessary updates. It is ideal to establish a direct relationship protocol with the developers of the system. This allows the user to interact with them so that new updates are related to current needs. Any given system should have large storage capacity. The use of video and high-resolution medical images requires a lot of space. Furthermore, it is ideal that the system's performance speed is enough to allow for dynamic work.

2.1.5 Data Display

The medical history and data registry are an essential part of the medical act. In many cases, the decision-making process is based on these records. Therefore, the way in which the act of recording each individual's medical history in the database is carried out is essential. To obtain more useful flows, it is important to get users involved in the design of these systems and platforms.

Nowadays, these systems are accumulating more and more data, and images can be digitised and re-analysed, thus generating even more data. Although such data lays the foundations for more objective and reliable records, they can become useless if they are not taken advantage of. There are many who have costly accumulated large amounts of data that have turned out to be useless, and have only succeeded in burying those who have worked to collect such data. Therefore, it is necessary to plan a multi-level management of both registries and data:

- Daily level: create dashboards showing previously decided parameters regarding the current or evolving reality of an individual process, the whole team or part of it. These dashboards should be dynamic and adaptable, so that average users are able to modify them. There are platforms designed for data analysis and display, such as Power BI ©. In competitive sports and in injury follow-up decision-making, access to immediate data and analysis are essential.
- Retrospective level of analysis: in most situations, the needs and problems that have to be addressed were not foreseen when data collection was being performed. This is why the data must be easily accessible so as to enable an analysis to detect, first, whether there is a big enough problem which justifies the effort of performing such analysis; second, to identify the causes and correlated factors leading to the problem taking place. Once these elements have been identified, it is time to draft a proposal to correct them. After these proposals have been implemented, it will be necessary to assess whether the problem has been corrected.
- Data mining level: the amount of data that accumulates around athletes and competing teams makes it reasonable to propose discrete analyses looking for algorithms that identify correlations between elements and situations that escape human perception.

Through this work, we should be able to produce predictive models that become the basis for true prevention. Up until now, prevention models have been based on the intuition and good faith of their proponents, but the qualities, which are particularly useful in reactive situations when an injury has to be diagnosed and treated, are not enough to reduce the risk of injury. Artificial intelligence could become more effective in developing more proactive prevention models and measures.

Unit 2.2 Developments in Sports and Technology, and New Data

Marti Casals

In recent years there have been important developments in sports, and, as we know, this not only creates great expectations but it also has consequences on economic, health and signings. Moreover, it generates a new area of knowledge. We have moved from writing down notes on what we are watching in a football or basketball game (notational analysis) to managing a wide range of records from increasingly sophisticated technologies.

The now famous armbands frequently worn by many athletes in training sessions and matches have sensors used to get biomedical information from the joints in which they are placed. In past years, a lot of work had to be done in terms of cross-checking information and coordinating different software. Now, tactical, physical and medical aspects are integrated and centralised into the cloud. In the near future, this will probably help to achieve greater multidisciplinarity across different current professions (managers, trainers, doctors, physiotherapists, physical trainers, analysts) or future ones, that is, those that will be integrated into the sports industry.

Nowadays, sports are influenced by records analysing a wide variety of environments, ranging from exercise physiology, psychology, and heat production to modern digital systems that analyse performance during competition. Different professional teams are starting to report information for injury control and follow-ups through different devices. But, how are these online sports health surveillance systems perceived by athletes and staff members? Is their use accepted or rejected? According to a recent study, they are helping improve the communication among the athlete, the coaching staff and the medical team (Barboza, Bolling, Nauta, Van Mechelen, and Verhagen, 2017). Furthermore, from the physician's point of view, this helps to get a deeper understanding of and control over the athlete, and to intervene when necessary (Barboza et al., 2017).
One of the main problems with the use of so much technology has to do with the validation of such instruments and measurement errors. In sports, many assessments are performed using tests and other tools but often the validity and reliability of these cannot be assured, even though they are widely used. Can we assure that the value recorded after an assessment is reliable? And does this reliability - or the lack of it - depend on the person responsible for the measurement? There is no doubt that we are currently making decisions, but are we processing data on the basis of records that we do not know to be true? Is this our responsibility? These are questions we must ask ourselves.

Nowadays, there is an ever-increasing number of records that can be created and used, which will surely continue to increase due to technological progress. Such availability of data poses a challenge that has to do with the selection of the most significant records, the creation of indexes to further knowledge acquisition and, above all, the creation of statistical models regarding the athletes' performance, adaptation and risk of injury. It is clear to the sports community closer to the scientific field that sports analysis and the

statistical and mathematical treatment of the enormous amount of data produced nowadays are paving the way to new areas of knowledge and business. In short, we now have more technology at our disposal, which produces much more data, but we still need to work on taking better decisions based on adequate models and statistical analyses.

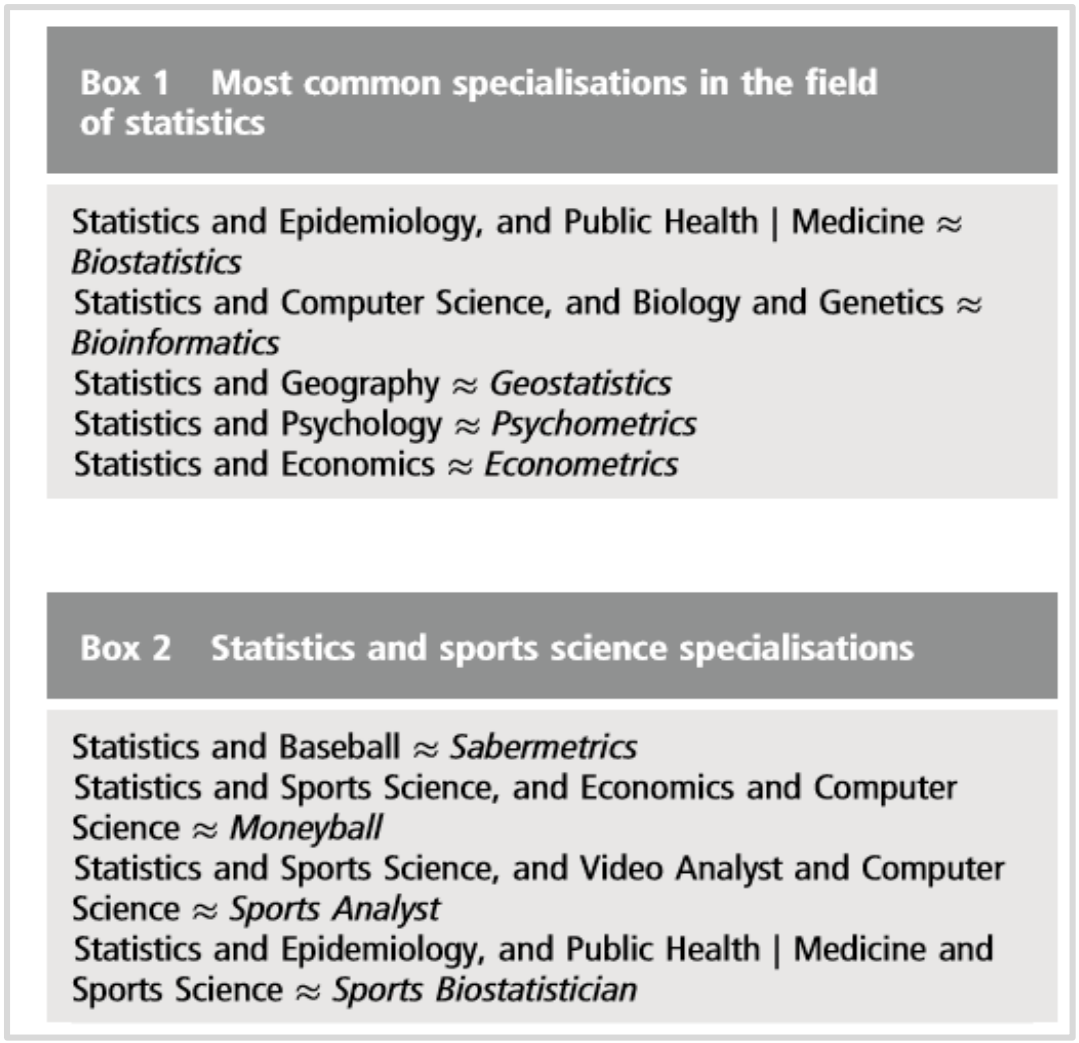
2.2.1 Statistics and Sports

There is much talk about statistics (or analytics) in sports. This coincides with the boom of statistics as a science and a profession. Being an analyst is considered one of the sexiest jobs in the 21st century. Is statistics really a fad or a trending topic in sports? History has shown that this is not the case. It is worth noting that Henry Chadwich came up with the notational analysis in 1861; that Professor James Connors produced the first heat map in sports in 1897; that Mr. Roth was the first statistician hired full-time by a professional team - this occurred in 1947. The list continues, and we could mention, for example, Michael Lewis's famous book, *Moneyball: The Art of Winning An Unfair Game*, published in 2003. The book narrates the true story of Billy Beane, the general manager of a modest Californian team who decided to use statistical approaches to aid decision-making - a role played by Brad Pitt in the famous film.

It is very common to wonder who might actually be interested in statistics applied to sports. The number of professionals interested in this area is surprising: sports managers or decision-makers, players, coaches, trainers, physical trainers, clinicians, retrainers, journalists, bookmakers, scouts or video analysts, sports scientists, academics, fans, psychologists, epidemiologists, scientists and experts in other fields, and statisticians.

There has been a growing interest in the application of statistics to science and in its increased scientific rigour in sports medicine and sports science in general. Statistics, together with other skills or professions, has set the bases for different specialisations, such as biostatistics, bioinformatics, geostatistics, econometrics and psychometrics (Figure 1). The Hollywood movie about *Moneyball* also helped to spark the interest of sports scientists and, in this way, to introduce different sports science specialisations, such as sabermetricians, Moneyball, sports analysts and sports biostatistics, which apply skill related to statistics (Figure 1).

Figure 2: Common specialisations in the Field of Statistics



Box 1 Most common specialisations in the field of statistics

Statistics and Epidemiology, and Public Health | Medicine ≈ *Biostatistics*
Statistics and Computer Science, and Biology and Genetics ≈ *Bioinformatics*
Statistics and Geography ≈ *Geostatistics*
Statistics and Psychology ≈ *Psychometrics*
Statistics and Economics ≈ *Econometrics*

Box 2 Statistics and sports science specialisations

Statistics and Baseball ≈ *Sabermetrics*
Statistics and Sports Science, and Economics and Computer Science ≈ *Moneyball*
Statistics and Sports Science, and Video Analyst and Computer Science ≈ *Sports Analyst*
Statistics and Epidemiology, and Public Health | Medicine and Sports Science ≈ *Sports Biostatistician*

Source: Casals and Finch, 2017

2.2.2 What are Statistics and How Useful are they?

Many of us have studied a Statistics course at university, but we no longer remember what it was about or why it was useful. Statistics is no longer defined as one of the branches of Mathematics, but as the science of learning from data, through which uncertainty is measured, controlled and communicated.

As a science, it is fairly young, and many people are still unaware of its existence. One proof of this is that statisticians are often confused with State workers, or are thought of as some kind of computer scientists who calculate averages, or perform calculations.

Statistics quantifies uncertainty and advises on how to collect data so that they provide as much information as possible. Biostatistics, which is the science that refers to the application and development of statistics in the life sciences and, more particularly, in the health sciences, has been studied in medicine. The big difference between statistics and

biostatistics is that in biostatistics one has to be familiar with other disciplines, such as epidemiology, genetics, demography, public health, and so on.

When we read scientific articles or want to conduct research projects, it is important to understand some different basic statistical terms:

- How to differentiate between population (the target of our study and all the data we want to know) and sample (a group or part of the population and the data we can work with).

  It is also important to know how to select a sample, the different sampling techniques (e.g. random, stratified), and their possible selection or information biases.

- In order to conduct accurate analyses, it is essential to know how to differentiate the nature, the level of measurement or scale and the type of variables (qualitative or quantitative) or characteristics on which we want to base our research.

- To use statistics correctly means to know what questions we want to answer. Questions such as what happens (descriptive statistics), what happened (diagnostic statistics), what will happen (predictive statistics) or what we should do (prescriptive statistics) point at different statistical tools. Another key distinction to keep in mind is that studies can explore observed data (descriptive statistics) or use observed data from a sample to draw inferences about the study population (inferential statistics). Descriptive statistics show us the data we have at that moment, for example, through the use of frequency tables and graphs, according to the variables we are studying. For quantitative variables, different measures of centralisation, dispersion, position and shape are also used. For example, at the University of North Carolina in Chapell Hill, they used to boast that their Geography students were the ones who achieved the highest average salary upon graduation, as opposed to students in other schools. What they did not know is that there was a student there who graduated in Geography due to a sports scholarship. This student was Michael Jordan, whose salary was obviously different from that of the other graduates. In this case, we should not calculate the average salary, but use another measure of centralisation, such as the median. As the infographer Alberto Cairo points out, "statistics do not lie, the person who manipulates them does". It would also be important to couple this measure of centralisation with some measure of dispersion in order to identify data variability. When describing quantitative variables, it is useful to use box-plots, which show various measures, such as the minimum, maximum, median, and first and third quartiles, and which allow us to discover possible outliers. Let's imagine that the sports biostatistician talks to the club's leading physician and tells them that currently the 3rd percentile (P3) of shoulder injuries in that club is 7 injuries. As sports medicine experts, we could interpret that 3% of the athletes in our club have 7 or less shoulder injuries. Knowing how to communicate and interpret this type of basic descriptive measures is essential.

- Statistical inference aims at drawing conclusions about a population on the basis of a sample. Two concepts should be highlighted: statistically significant differences and clinically relevant differences. Which of the two concepts is more relevant? Probably the second, but to answer this, we need the first one, too. We live in a world where we are constantly comparing ourselves. A point of departure that allows us to compare, relate, test or estimate is what is contrast or hypothesis testing. There is also the concept of modelling. The base of many published scientific conclusions is the concept of statistical significance, usually assessed by an index called a p-value. A p-value is the probability, on the basis of a certain statistical model, that a statistic summarising some characteristic of the data (for example, the difference in means when comparing two groups) is equal to or more extreme than the observed value. However, although the p-value is a useful statistical measure, it is often misused, abused and misinterpreted. This has led some scientific journals to discourage its use. In this context, the American Statistical Association (ASA) has made a formal statement towards the scientific community, clarifying some widely accepted principles that are implicit in the correct use and interpretation of the p-value (The American Statistical Association, 2016). A single index should not be a substitute for scientific reasoning. Some alternatives to this index have also been proposed (such as the confidence interval [CI], Cohen's d, measures of effect, etc.) and are worth keeping in mind.

- When we relate two quantitative variables that have a linear relationship, it is said that these variables are correlated. This concept (linear relationship) is often confused with causality, a quite different concept for which design and other aspects have to be considered.

- Often, the target or dependent variable is compared to another characteristic of interest or independent variable. However, in sports medicine, as in other fields, the main objective (e.g.: to get injured [yes/no]) is often associated with more than one covariate (e.g.: previous injury, age, playing surface, time of the season, etc.) and multiple factors - some latent, and above all dynamic - that can influence it have to be considered. The specification and validation of statistical regression models, and the inclusion of confounding or modifying variables, are aspects that need to be verified in order to understand the aetiology of the injuries or the factors associated with them, as well as the use of predictive models.

- Most sports medicine questions that a clinician wants answers to are: diagnosis, prognosis and the search for risk factors for disease or injury. These can be variable factors (e.g. if an athlete smokes, which may increase the risk of a certain disease) and non-modifiable factors (e.g. age). In sports medicine we also often talk about intrinsic factors (such as age, ethnicity, gender, genetic predisposition, previous history of injury) and extrinsic factors (such as nutrition, psychological factors, muscle strength balance, workload, fatigue, flexibility). The physician often tries to acknowledge all of these, and there is nothing better than a statistical model that identifies these factors to help them do so. The last decade has seen work on biostatistics applied to personalised medicine, which attempts to answer what dose of treatment to give to a patient based on their unique characteristics, since

treatment does not necessarily have to be the same for all patients suffering from the same disease or injury (goo.gl/gwCUGD). However, knowing the risk factors or identifying subgroups that have a higher or lower risk of injury is often not enough. It is necessary to try and find out how and why the injury or disease has developed.

2.2.3 Research Methodology and Epidemiological Training

Life science professionals cannot underestimate the importance of research, and sports medicine is no exception. As a science, it acquires knowledge through the scientific method. To do research, it is important to have the ability to ask questions and to follow the scientific method. Intuitive knowledge or unsubstantiated assumptions will simply not do. The scientific method is the succession of steps (observation, induction, hypothesis; proof or test of the hypothesis by experimentation; demonstration or refutation of the hypothesis; and thesis or scientific theory) that scientists follow to make new discoveries and to test hitherto unknown hypotheses. Research and the stages of the scientific method are related to the main sections often displayed in scientific articles (see Table 1) (Mabrouki, and Bosch, 2007).

Table 1: Stages of the Scientific Method

Stages of the Scientific Method	MAIN SECTIONS OF A SCIENTIFIC ARTICLE
Understanding the problem to be studied	Introduction
Establishing a Hypothesis	
Data Collection	Materials and Methodology
Data Analysis	Results
Results Interpretation	Discussion
Conclusions	

Source: Author's production.

A key aspect when carrying out research is to know how to ask good questions, following the scientific method and knowing the different epidemiological designs, epidemiological measures (frequency, association, impact) and, above all, following scientifically-agreed guidelines such as Strengthening the Reporting of Observational Studies in Epidemiology (STROBE), Consolidated Standards of Reporting Trials (CONSORT), Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), and WHO Injury Surveillance Guidelines. Epidemiology is the science that studies the distribution and aetiology of diseases or injuries in a certain population. In the sports industry, the International Olympic Committee (IOC) has been working to improve the health of athletes for years with specialised epidemiology and research groups from all over the world.

In sports medicine there are different profiles that are related, in turn, to different skills and concerns. All the profiles described below are necessary for a team or a club, in addition to the interest, enthusiasm and passion for sports medicine.

- Clinical profile: meeting and diagnosing patients on a day-to-day basis should not alienate one from clinical practice or the reality of sports medicine.
- Epidemiological profile: reporting information on injuries, studying their distribution and possible causes helps to prevent them and monitor athletes.
- Scientific profile: writing and understanding scientific papers following clinical practice guidelines brings professionals closer to the advances in sports medicine.
- Video analyst profile: watching matches or training sessions live or on TV and trying to understand the evolution of sports helps to ask better scientific or clinical questions.
- Statistician/analyst profile: questioning and trying to understand the patterns and uncertainty of events will help to have a more quantitative profile.

Debates about whether someone is more of a clinician or an epidemiologist are pointless, since both skills are needed in the professional world. There is often still a divide between clinical practice and research, and between practitioners and academics/researchers. Even though not all of us do research, we should be active consumers of the research literature, which will provide us with more knowledge and rigour in our actions. Recently, this division is becoming less and less noticeable, thanks to the need for more multidisciplinary work and the need to know how to interpret much of the data that is being recorded. The British Journal of Sports Medicine (BJSM) is currently writing several educational editorials that highlight epidemiology and statistics. This brings professionals working in sports teams closer to the academic world (Nielsen, et al., 2017a; Nielsen, et al., 2017b). For example, these editorials are helping coaches and physicians to know how to read scientific articles, and to distinguish between measures such as prevalence and injury incidence. Different scientists are trying to improve different aspects, as is the case with other disciplines. John Ioannidis (2005), one of the pioneers of the so-called meta-science, a discipline that analyses the work of other scientists and checks whether the fundamental rules that define good science are respected, found that there is great room for improvement for most of the scientific articles he analysed. In this sense, work is being done on two of the key issues - reproducibility and replicability of data - to address this scientific crisis.

2.2.4 The Sports Biostatistician: A New Profession Contributing to Injury Prevention

"The new professional speciality of sports biostatistics can help in the optimisation of injury data to quantify injuries, understand their possible causes and thus be able to prevent them" ("Sports Biostatistics Calls for Court to Prevent Injuries", 2017, https://goo.gl/B633Kg), according to a new study published in Injury Prevention (Casals, and Finch, 2016). In this research, Martí Casals, professor and researcher at the Sport Performance Analysis Research Group (SPARG) of the University of Vic-Central University of Catalonia (UVic-UCC), currently a biostatistician at FC Barcelona and with experience in this field in an NBA team, together with Caroline Finch, from the Australian

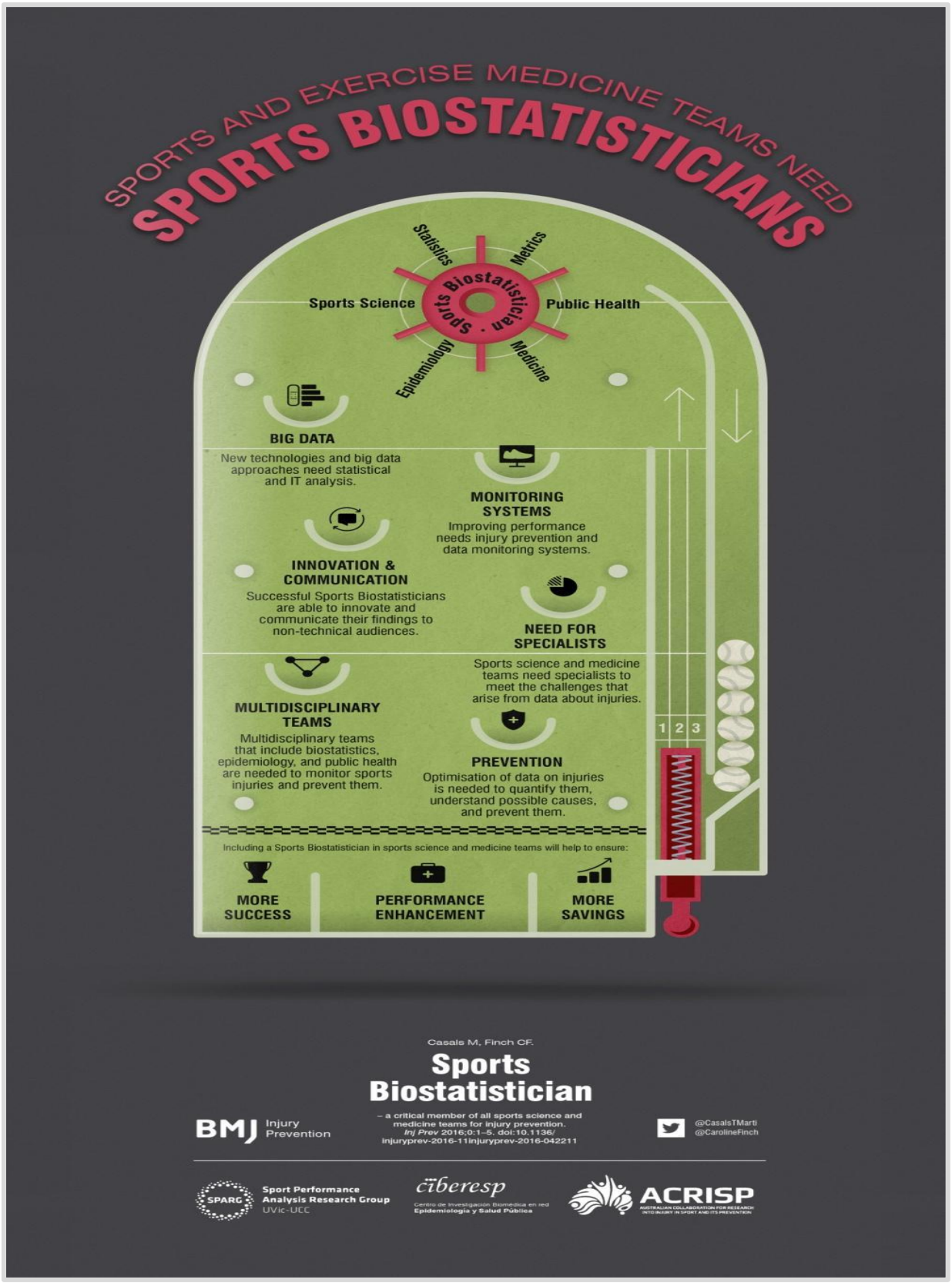
Collaboration for Research into Sports and its Prevention (Federation University Australia), which is one of the nine research centres recognised by the IOC for the prevention of injuries and the protection of athletes' health, describe the emerging field of sports biostatistics (Casals, and Finch, 2016).

> To talk about performance is also to talk indirectly about injury prevention and injury surveillance systems... Sports science and sports medicine need specialists to respond to the challenges that arise with injury data. One of the professions that can perform these functions is the speciality in sports biostatistician, best known in the US or Australia. (Casals, and Finch, cited in "La estadística también ayuda a prevenir lesiones", 2016, https://goo.gl/UtpUHd).

> This new professional profile requires knowledge of injury aetiology, strong skills in statistics, epidemiology, and data computer programming, as well as strong communication skills, as this professional must communicate their findings to a wide range of people in the sports community, from parents to coaches, players, sports physicians, clinicians, physical trainers, physiotherapists, sports scientists, epidemiologists and club decision-makers. (Pichel Andrés, 2017).

In addition to sports analysts, elite sports clubs are already starting to take into account sports biostatisticians. The following infographic, published in the British Journal of Sports Medicine, shows a summary of the characteristics of this speciality (Casals, Bekker, and Finch, 2017).

Figure 3: Sports Bioetatisticians



Source: Casals et al., 2017.

References

Barboza, S. D., Bolling, C. S., Nauta, J., Van Mechelen, M., and Verhagen, E. (2017). Acceptability and perceptions of end-users towards an online sports-health surveillance system. *BMJ Open Sport & Exercise Medicine, 3*(1).

Casals, M., and Finch, C. F. (2016). Sports Biostatisticians – a critical member of all sports science and medicine teams for injury prevention. *Injury Prevention*, *23*(6), 423-427.

Casals, M., Bekker, S., and Finch, C. F. (2017). Infographic: Sports Biostatisticians – a critical member of all sports science and medicine teams for injury prevention. *Inj Prev.* 2017 Dec;23(6):423-427.

Ioannidis, J. P. (2005). Why most published research findings are false. *PLoS medicine*, 2(8).

La biestadística deportiva pide cancha para evitar lesiones (Sports bistatistics asks for a court to prevent injuries). (January 3rd, 2017). Retrieved from http://www.immedicohospitalario.es/noticia/10183/la-biestadistica-deportiva-pide-cancha-para-evitar-lesiones

La estadística también ayuda a prevenir lesiones (Statistics Also Help Prevent Injuries.) (January 5th, 2017). *Sinc, la ciencia es noticia* [Digital version]. Retrieved from http://www.agenciasinc.es/Noticias/La-estadistica-tambien-ayuda-a-prevenir-lesiones

Mabrouki, K., and Bosch, F. (2007). Redacción científica en biomedicina. Lo que hay que saber (Scientific writing in biomedicine. What you need to know). Barcelona, Spain. Prous Science.

Nielsen, R. O., Debes-Kristensen, K., Hulme, A., Bertelsen, M. L., Møller, M., Parner, E. T., and Mansournia, M. A. (2017a). Are prevalence measures better than incidence measures in sports injury research? *Br J Sports Med. October 13th, 2017.*

Nielsen, R. O., Chapman, C. M., Louis, W. R., Stovitz, S. D., Mansournia, M. A., Windt, J., Møller, M., Thorlund Parner, E., Hulme, A., Lejbach Bertelsen, M., Finch, C. F., Casals, M., and Verhagen, E. (2017b). Seven sins when interpreting statistics in sports injury science. *Br J Sports Med. December 20th, 2017.*

Nielsen, R. O., Bertelsen, M. L., Verhagen, E., Mansournia, M. A., Hulme, A., Møller, M., and Casals, M. (2017). When is a study result important for athletes, clinicians and team coaches/staff? *British Journal of Sports Medicine*, *51,* 1454-1455.

Pichel Andrés, J. (January 16th, 2017). Bioestadística y “big data” para prevenir las lesiones deportivas (Biostatistics and "big data" to prevent sports injuries). Retrieved from https://www.bez.es/882750780/bioestadistica-big-data-para-prevenir-lesiones.html

The American Statistical Association (ASA). (March 7th, 2016). American Statistical Association Releases Statement On Statistical Significance and *P*-Values. Provides Principles to Improve the Conduct and Interpretation of Quantitative Science. Retrieved from www.amstat.org/asa/files/pdfs/P-ValueStatement.pdf

Verhagen, E., Stovitz, S. D., Mansournia, M. A., Nielsen, R. O., and Shrier, I. (2017). BJSM educational editorials: methods matter. *Br J Sports Med. August 17th, 2017*