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PHYSICAL DEMANDS AND INJURY RISKS TEAM SPORTS

PHYSICAL DEMANDS IN TEAM SPORTS

Physical demands in team sports

This course's main goal is to provide a theoretical and practical frame based mainly on updated scientific evidence. This will allow for an advance on our knowledge and, consequently, an improvement on tasks design and decision making, mainly, in the physical education area.

Having said that, I am going to introduce the curse split in the different modules we will cover. Module 1 will be about physical demands (external load) in team sports. No matter which sports we could practice, train or coach, we need to know their typical demands, in order to be able to design and prescribe training to our teams and, consequently, to our players. That way, they will try to practice sports in the best possible conditions, either in training, or in competitions themselves.

The first curse will be a general version of all team sports. Obviously, with some detailed examples of basketball or football and also other sports, like rugby, which will make us understand better what later will be our focus: basketball.

Module 2 will be about microtechnology application for optimizing performance in team sports. It is clear that technology is already part of sports and it is going to stay. Microtechnology integration in team sports is getting more and more important and, specifically, in performance optimization it is becoming more and more significant and it has no limits. This way, in broad brushstrokes, we will discuss all this, so you can have this vision and, in a future, you can apply it to your own teams.

Module 3 will be about the application of microtechnology in injury prevention in team sports. Although it is clear that one of the pillars is sport performance, it is not less evident that prevention on injury risks is another key and essential concept for any trainer that pretends to develop a training career thoroughly. This block oriented toward injury prevention can also be discussed together with the implementation of microtechnology, as we will discover when we are fully immersed on module 3.

Finally, module 4 will be based on practical application of systems based on inertial measurement units (IMU) on different tests for collective sports players or situational sports players. So, this section pretends to transmit the ways in which we can apply technology to know and evaluate different aspects that are part of the training for athletes and which will help us later in performance individualization and optimization. Sport is one of the most important social phenomena in our society. Who does not remember Usain Bolt pulverizing the 100 meters world record in Berlin, stopping the stopwatch in 9.58 sec?

Figure 1: Usain Bolt

Source: [Untitled image of Usain Bolt], 2016, https://bit.ly/3enF5SV

And, why don't we talk about resistance if we remember the heroic feat we could witness not so long ago? Kenyan runner Eliud Kipchoge, in Berlin, could improve his time of 2 hours and 2 minutes in 2016 Berlin Marathon. But he did not stop there, soon after that he became the first man in running the marathon distance in less than 2 hours and, in spite of setting this new mark, he got it in conditions that are not approved for records.

Figure 2: Eliud Kipchoge

Source: [Untitled image of Eluid Kipchoge], 2019, https://bit.ly/3abjvxF

Another example is Vitaly Shcherbo. For the ones who do not remember him, he was an excellent gymnast and one of the best doing the iron cross figure; he got five gold medals in five days in Barcelona Olympics in 1992.

Figure 3: Vitaly Shcherbo

Source: [Untitled image of Vitaly Scherbo], 2018, https://bit.ly/34F7Rdb

On the other hand, who does not remember the Michael Jordan free throw jump in the slam dunk contest in 1988?

Figure 4: Michael Jordan

Source: [Untitled image of Michael Jordan], 2015, https://bit.ly/2yivvjE

Another sport hit was the gift in form of goal that hundreds of Spanish enjoyed and celebrated when Iniesta scored in the World Cup in South Africa and he gave them the World Championship.

Figure 5: Andrés Iniesta

Source: [Untitled image of Andrés Iniesta], 2017, https://bit.ly/2xxqPXa

In each of these sports disciplines, these athletes could touch millions around the world. That is why sport in our society is so relevant.

The first main categorization we can do so far is the classification between individual and team sports. From now on, we are going to focus on the latter.

In the following figures you will find images related to champion teams sport success: FC Barcelona football and basketball teams who won the championship in different competitions, the NBA Golden State Warriors who got the NBA championship ring, the Spain national football and basketball teams holding the world trophies.

Figure 6: FC Barcelona football team

Source: [Untitled image of F.C Barcelona football team], 2019, https://bit.ly/2VfqEZL

Figure 7: FC Barcelona basketball team

Source: [Untitled image of F.C Barcelona basketball team], 2018, https://bit.ly/2xxx7pK

Figure 8: *Golden State Warriors*

Source: [Untitled image of Golden State Warriors], 2018, https://bit.ly/2XGcq5Q

Figure 9: Spain national football team

Source: [Untitled image Spain national team], 2012, https://bit.ly/2VuSqQU

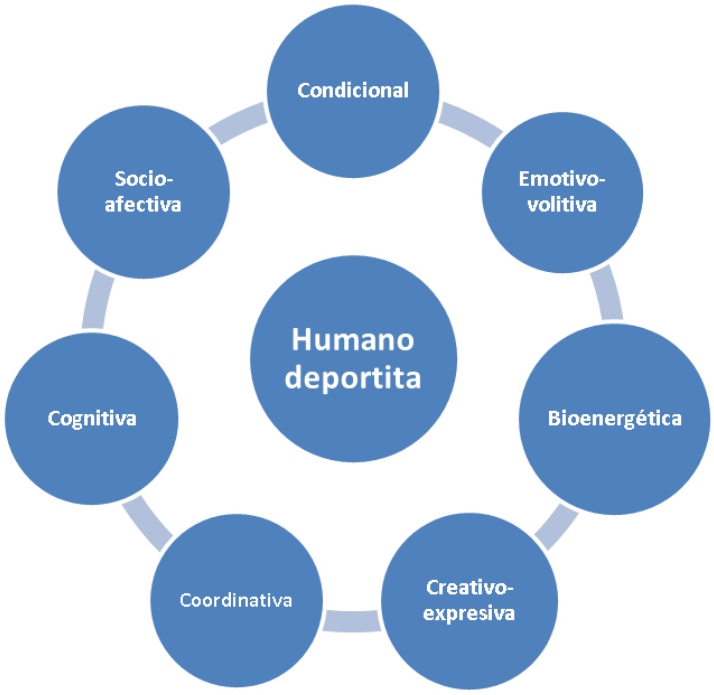
Figure 10: Spain national basketball team

Source: [Untitled image Spain national basketball team], 2019, https://bit.ly/2RDzA8L

These teams are, mainly, made up of some athletes of the stature of Leo Messi, Stephen Curry and Juan Carlos Navarro; all of them are top unique players in their different

disciplines. What do all these players have in common? All of them, without exception, are defined by the different structures, the different systems that define the athlete. Among others, said structures are: the conditional or physical structure, the technical or coordination structure, the cognitive or tactical structure, the creative-expressive structure and a series of structures that are part of any human being and, consequently, human beings that practice sports.

Figure 11: Structures that are part of the athlete human being



Condicional	Conditional
Emotivo-volitiva	Emotional-volitional
Bioenergética	Bioenergetic
Creativo-expresiva	Creative-expressive
Coordinativa	Coordinative

Cognitiva	Cognitiva
Socio-afectiva	Social-affective
Mental	Mental
Humano deportista	Athlete human

Source: own adaptation based in Seirul·lo Vargas, 1998 quoted in Reverter-Masià, Ribera-Nebot y Picó-Benet, p. 19

The thing that makes them unique is that these athletes have their structure levels raised to the maximum in such a way that optimization in the sports they practice is also raised to the maximum and this allows them to reach sport excellence. In general, sport performance is conditioned mainly by two aspects. On the one hand, the genetic part: all of our qualities are determined, whether we like it or not, by the genetic information that each one of us has. On the other hand, we are dependent on our personal time as an athlete. That is to say, all the training sessions and all the competitions or matches that athletes are part of in their athletic career are going to influence, to a greater or lesser extent, their sport performance. What we do not know is how much we can affect that path that players do in their athletic career. What is clear, in fact, is that coaches and trainers can make a contribution to make a positive influence in the sport performance optimization process.

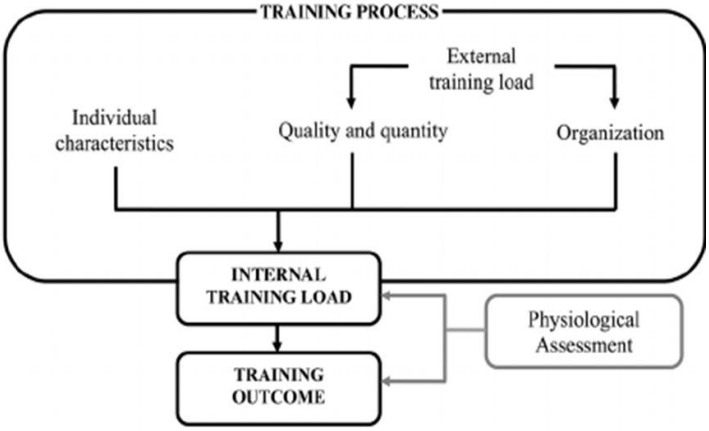
Nowadays, sports have changed from being a free time and amusement activity to a professionalized industry with the main goal of making money. This means that it has become a business and that has a series of implications, as, for example, sport schedules changes to increase the amount of matches that are played each week and during the whole season.

This way, as we have seen, the schedules are extended in order to include many more competitions during the whole season. This brings about more pressure not only on young athletes, but also on adults to optimize their sport performance. This is going to have a direct and definite influence on the main demand we want to focus on: physical demands or training and competition load. That way, not only young athletes but also elite adult athletes have considered and are considering increasing their training and competition loads in volume and intensity, throughout the season and their athletic careers. As a consequence, technical teams in their environments will try to optimize their sport performance through the different contents, means, methods and paths they may find useful for achieving this goal.

The first big question we have to ask ourselves is: what is load? Below, there are some definitions by different authors. According to Zinti (1991), load is the effect that comes from the effort an athlete makes on his/her functional state.

That is to say, what occurs in the athlete´s behavior and how the training stimulus affects the athlete? Another definition is the one given by González-Badillo y Ribas Serna (2002) that defines the internal or real load as the biological and psychological demands caused by the external or proposed load, which involves athlete´s training or competition. In relation to this definition, we understand external load as a synonym for physical demands. In figure 12, Impellizzeri, Rampinini y Marcora (2005) shows the way the training process is structured.

Figure 12: Training process



Source: Impellizeri et. al., 2005, p. 584

In the first place, it shows the external load or physical demands that will depend on the quantity and the quality and, on the other hand, on the organization, e.g. on the way we structure this training, whether inside the session and/or during the microcycle. All this will depend, obviously, on the individual characteristics of each one of the players and on the collective characteristics of the team itself.

How will each of the athletes react to a certain amount of physical demands? Since each of them will have an internal reaction that could be different in function, not only on the external load, but also on individual characteristics. This response will produce a result that could be evaluated physiologically.

That way, the physiological evaluation of the training process and of its result will allow us to improve the interpretation of the physical tests to verify the effectiveness of training programs, e.g. we will be able to interpret the tests we do in a better way.

Besides, we will be able to evaluate organization of dynamics in training loads, so that we can design the different periodization strategies with better criteria. We will be able to identify, also, the athletes that do not react well to different stimuli that we have proposed to have a better control of coincidence between the expected training and the one that was planned by the trainer. This means that what we have drawn in a paper matches or not the reaction that each of the players has had, individually and collectively. This will also allow us to modify the training process, before evaluating its results allowing us, somehow, to know what is going to happen when we propose a particular training session on a paper. In figure 13 what we see is a way of interpreting the training load. Training and/or competition load is a process made up of different aspects, such as psychological, physiological or social. In each of the two first aspects two inseparable binomials will occur always. We refer to the stress or stimulus, together with the correspondent fatigue and with recovery. These two concepts are the ones that we are going to take into account in order to optimize the training loads always.

Figure 13: Balance between stress and recovery in sports

Estímulo	Stimulus
Proceso	Process
Psicológico. Estrés/recuperación	Psychological. Stress/recovery
Fisiológico. Estrés/recuperación	Physiological. Stress/ recovery

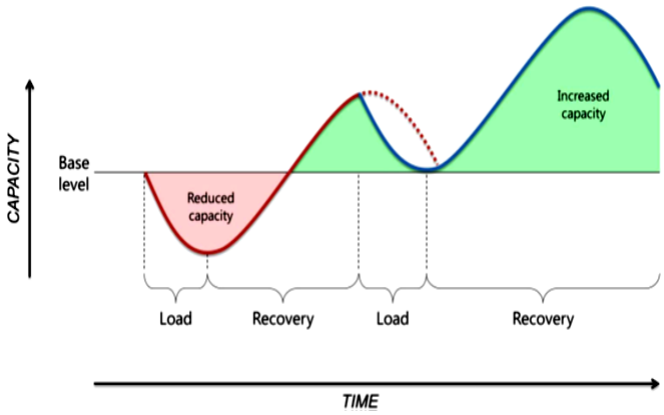
Social	Social
Resultado	Result
Equilibrio atlético	Athletic balance
Aumento rendimiento	Increase in performance
Adaptación	Adaptation
Maladaptación	Maladaptation
Lesiones Enfermedades Sobreentrenamiento	Injuries Sicknesses Overtraining

Source: own adaptation of Brink, Visscher, Coutts y Lemmink, 2010

These three processes altogether integrated will produce a series of changes, or modifications and, as a consequence, a result in each of our athletes, according to the way that the relation between stress-stimulus and expected recovery is established. That way, two possible situations will happen: one that will allow performance optimization and improvement, and the other one that will improve probabilities of suffering a sport injury and/or sickness.

This way, if we are based on the 1963 Selye´s biological adaptation law, taken as one of the most important principles in training theory, we know that, according to proposed loads dynamics, we are going to provide a series of adaptations that are going to help us to improve sport performance (especially if we think on the athlete´s bioenergetics and conditional structures). Therefore, we must use this principle as a base for optimizing sport performance.

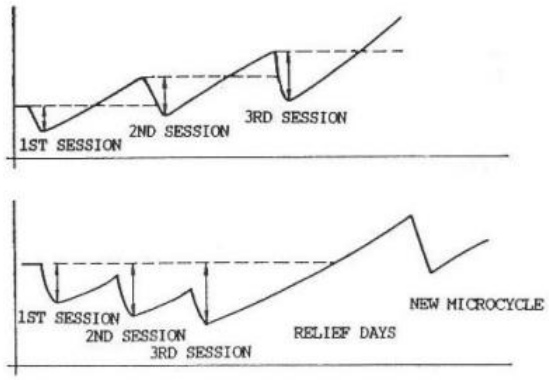
Figure 14: Training adaptation principle



Source: Soligard et al., 2016, p. 1031.

Just as we are developing this, there will be two possible essential responses, according to the way in which we structure load dynamics. One in which positive adaptations are going to happen and we will improve, and another one in which exactly the contrary can happen, which means that positive expected adaptations will not happen. This can be explicitly and clearly observed in figure 15 and it is also a summary of adequate or inadequate training.

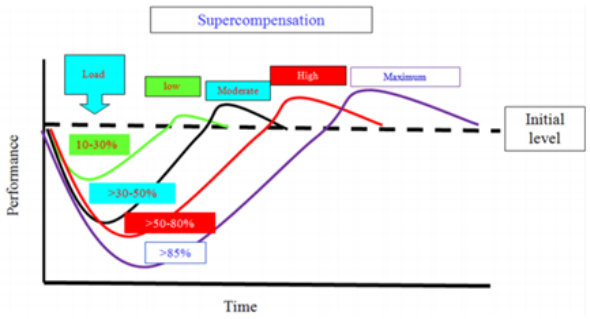
Figure 15: Adequate versus inadequate training



Source: Viru y Viru, 2000, p. 71.

And if we observe figure 16, taking Fernando Naclerio's article as a reference, we can see that adaptations achieved will depend on the load magnitude we are proposing. In other words, we can make a distinction between low, moderate and maximum o high load and that will generate more adaptations, according to the load magnitude we propose, as long as it is not an excessive load or one that goes beyond the limits, as we will see later on.

Figure 16: Theoretical adaptations depending on the load magnitude proposed



Source: Naclerio, Moody y Chapman, 2013, p. 359.

Usually, programed loads are controlled by the coaching staff assuming the team state. But the real effect of stimuli on each player is not taken into account, e.g. in an individual way. It is obvious that each athlete responds differently to the same training or competition stimulus.

This way, we can see that the result will always depend on the individual characteristics of the players, just as Impellizieri (et al., 2005) already pointed out in figure 12, in which it can be seen that not only internal, but also the external load should be included in the analysis, in order to have a better estimation of which is the real state of the players. External load can be analyzed, mainly, through time/movement analysis by video analysis and also using inertial and/or positioning microtechnology (global or local), topics that will be dealt with later on. In relation to internal load, we can measure and evaluate players' reaction by looking at variables like heart rate, lactate, oxygen consumption, different substrates depletion like sodium, potassium, etc or by looking at muscle damage that some enzymes like creatine kinase may suffer.

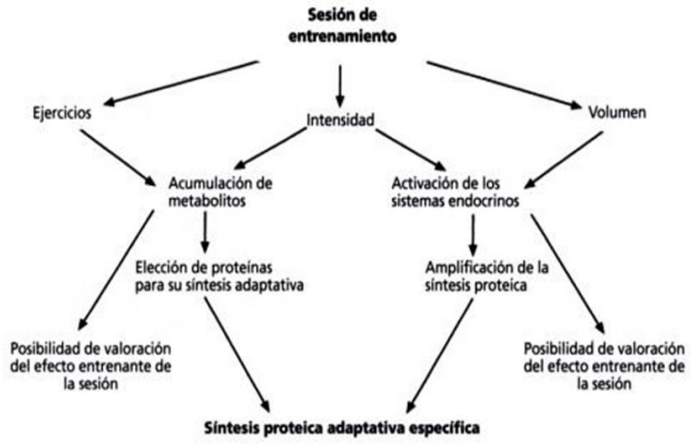
If we go back to the load-fatigue binomial, essential in players' reaction, we should properly manage his/her work and recovery, so that his/her performance does not get

worse, either because of excessive stimulus or lack of it (Kuipers, 1998). In other words, we should pay attention not only to excessive training, but also if the proposed training load is insufficient. And that leads us to the following question: How do we measure stimulus? Stimulus is measured by its volume.

As an example, in force: what would be the volume? The tension that is generated in each of the actions by time or by action unit. And how do the different body effects manifest? The different effects in the system manifest through changes that take place in performance and through induced biological modifications. These biological modifications imply changes at cellular levels, e.g. it means that protein synthesis that will bring about changes in the most important different metabolic pathways. Getting an appropriate stimulus depends, just as we said, on the current reaction state of the individual and on the stimulus characteristics.

In other words, magnitude will bring about physiological changes, either at a neuromuscular, cardiovascular, respiratory and metabolic level and it will also generate mechanical changes in other variables, such as force, speed or a combination of both, like power. If we observe Viru (figure 9) schema, proposed back in 1995, we can see that in a training session we will have three essential pillars: exercises, intensity and volume. From that point, as a result, there will be a metabolite accumulation or an activation of the endocrine system, which, in turn, will produce a selection of protein synthesis and that will take us to a synthesis of specific protein from the training stimulus we have proposed to our athletes

Figure 17: Pillars in a training session



Sesión de entrenamiento	Training session
Ejercicios	Exercises
Intensidad	Intensity
Volumen	Volume
Acumulación de metabolitos	Metabolites accumulation
Activación de sistemas endócrinos	Endrocrine systems activation
Elección de proteínas para su síntesis adaptativa	Proteins selection for their adaptative synthesis
Amplificación de la síntesis proteica	Protein synthesis amplification
Posibilidad de valoración del efecto entrenante de la sesión	Possibility of assessment of the workout effect of the session
Posibilidad de valoración del efecto entrenante de la sesión	Possibility of assessment of the workout effect of the session
Síntesis proteica adaptativa específica	Specific adaptative protein synthesis

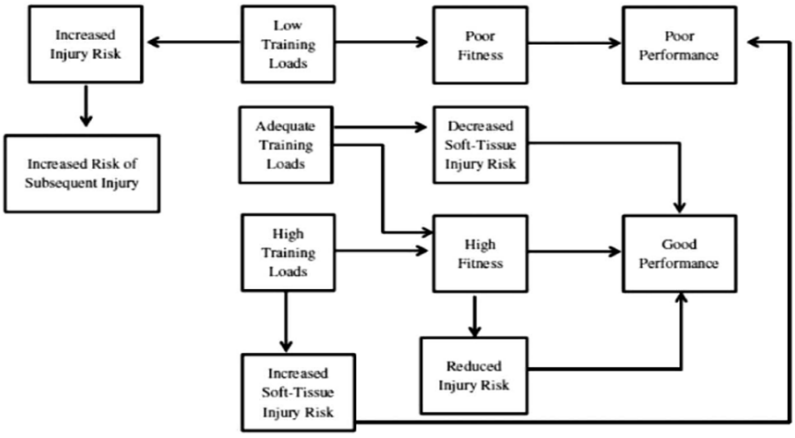
Source: own adaptation based in Viru, 1995.

We have different ways of classifying training loads, according to their magnitude. If we start for the bottom, on the basis that it is low or very low, we can say that is an insufficient load for training, e.g. a stimulus that will not generate an adaptation. Nevertheless, we can propose a low load with a recovery goal in mind, just as its name implies, for facilitating homeostasis in the athlete´s body in reaction to a previous stimulus, which will not have an optimizer effect.

We can refer to a load to keep fit, that will only help us to keep the performance we already had and we can also refer to a workout load. The workout load will be the one that will allow us to improve performance. This load will allow improvement in our athletes. Above that load magnitude there might be another one called excessive load that will not have positive effects on athletes, because it will have exceeded the limits to which they can adapt. It is true anyway, and this happens often in sports, that you, as a trainer or coach, decide in a selective and controlled way that the team needs a dose of something different, e.g. a stimulus that, although it does not generate positive effects at the physiological level, could have an effect on athletes´ other systems like the emotional-volitional. We should take into account the available information and that each one of us should judge whether is appropriate to use it or not.

Making a review of recent scientific bibliography we can make a very simple summary of load classification according to its magnitude: three types of loads.

Figure 18: Connection between physical qualities, training load and injury risk in team sports

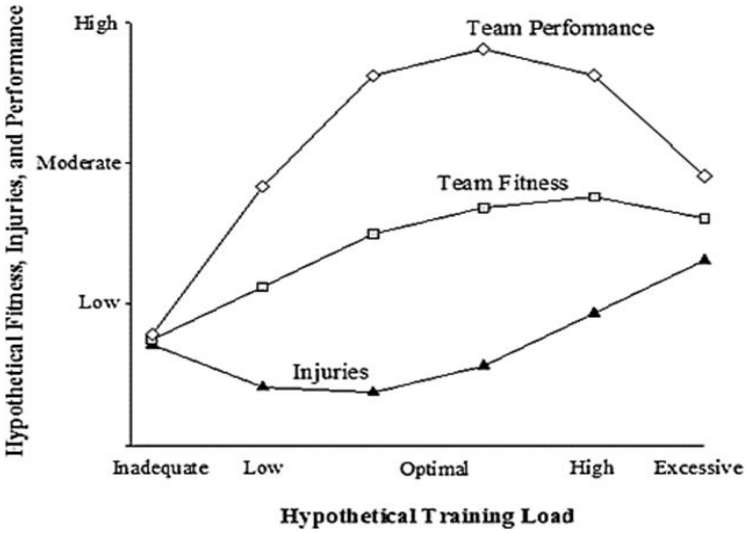


Source: Gabbett, 2016, p.7

To begin with, we can define low loads as the ones that are going to produce a poor fitness adaptation and, consequently, a poor performance and, because they are insufficient, they can increase injury risk. The other block is made up of the appropriate or ideal training loads, e.g. the ones that allow us to reduce injury risk and, at the same time, increase the athlete´s fitness condition, which, in turn, will bring about better sport performance. Finally, high loads that can be worked together with a particular increase in the fitness condition and they can even improve performance temporarily. However, frequent high loads implementation will bring about an increase in injury risk. As a consequence, our goal as coaches, as trainers supports will be, in general, to try to find the ideal load in order to achieve established goals.

If we use Tim Gabbett (figure 19) graphic as a base, we can see that a connection between these three concepts is made. The concept of team sport performance, the concept of suffering from an injury and the fitness concept.

Figure 19: Hypothetical connection between training load, fitness, injuries and performance



Source: Gabbett, 2016, p. 2.

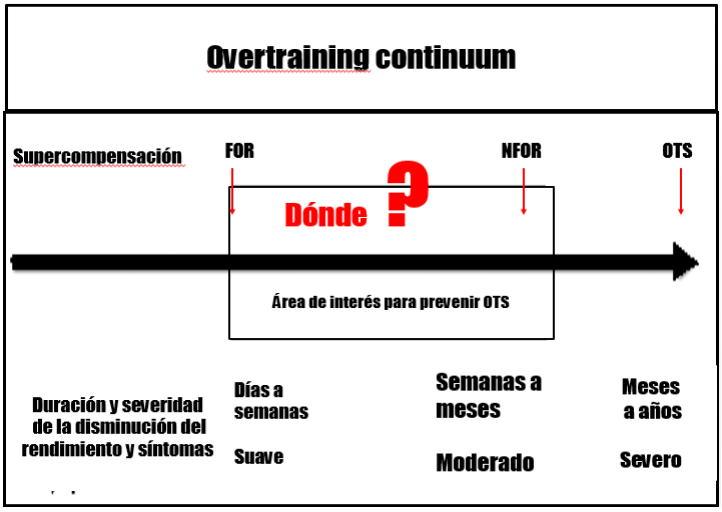
These three concepts interact with each other, in relation to the loads we give athletes: inadequate, low, optimal or excessive. If loads are high or excessive, injuries will increase, but neither performance nor team fitness will be the highest. If we go to the opposite extreme and we reduce load to very low, we can reduce injury risk, but, again, performance and team fitness, in this case, will not be optimal. However, if we can find the adequate training dose, in fact, we can get the balance between the three concepts we have discussed and, this way, achieve the maximum level of the hypothetical team performance, a low risk for injuries and a high fitness level. As a consequence, improvement in team performance comes from, among other factors, the prescription of an optimal amount of training, together with adequate recovery periods to achieve the highest adaptation level before competition.

Which is the other problem for team sports?

Another problem we may find when we periodize and apply training loads is that there are differences, not only in the technical and tactical skills of our players, but also in their conditional abilities and that becomes the big difficulty for optimizing sport performance. That is why it is so difficult to find the right dose of loads for most players in the team at the different moments through the week and/or the season, especially for

the most important ones. Another issue we should understand in this module is the overtraining syndrome as a continuum process.

Figure 20: Continuum overtraining process



Overtraining continuum	Overtraining continuum
Supercompensación	Supercompensation
FOR	FOR
NFOR	NFOR
OTS	OTS
¿Dónde?	Where?
Área de interés para prevenir OTS	Area of interest to prevent OTS
Duración y severidad de la disminución de rendimiento y síntomas	Duration and severity of reduction of performance and symptoms

Días a semanas	Days to weeks
Semanas a meses	Weeks to months
Meses a años	Months to years
Suave	Soft
Moderado	Moderate
Severo	Severe

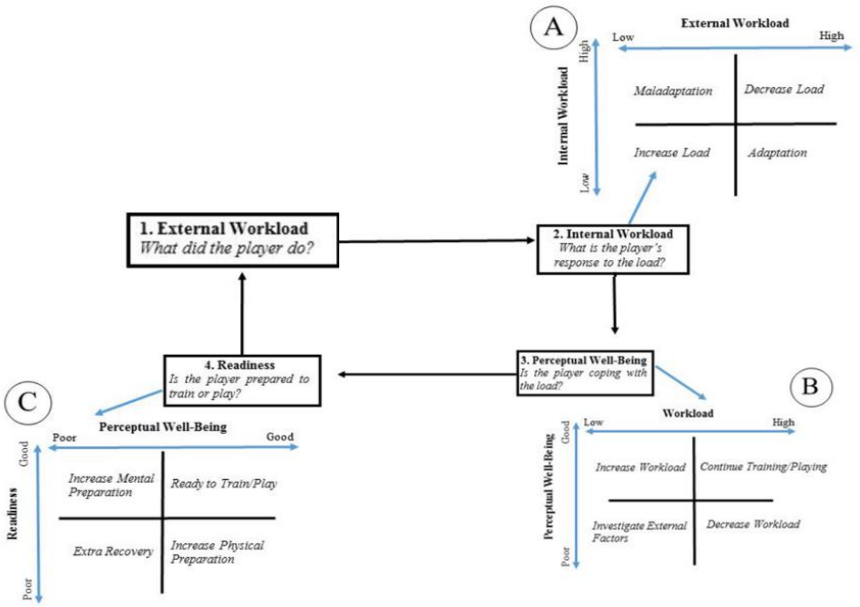
Source: own adaptation of Brink, et al., 2010

This interpretation implies that there is not a particular period in which we are overtrained, e.g. we cannot delimit that moment in a period, but we can distinguish different zones. Among them, in the first place, there appears the area known as functional overreaching, in which our players' performance is under their potential level, but it is a state we often look for as part of our periodization. For example, in preseason, by applying certain training loads, sometimes, we want to achieve some results in the mid or long term, not in the short term. For that purpose, we apply different stimuli in an amount of time that could generate certain accumulated fatigue that, once overcome as a result of adequate pauses, will generate a long term adaptation.

We could find another zone known as non-functional overreaching zone that could have an extension of weeks or months. This is not achieved on purpose, but it is the result of a bad training periodization and, as a consequence, a wrong choice of our training proposals together with the competitions calendar. If we keep progressing in this continuum, we could get to the famous overtraining syndrome that could have terrible consequences, not only for performance but also for the athlete's health. It is true that while it is quite easy to be in the first zone and sometimes even on the second one, reaching the overtraining syndrome is not usual.

We have already highlighted the significance and the influence of training load, and matches and competitions supported by our players and teams. This is important for achieving performance optimization and injury prevention. As a consequence, we should monitor, control and evaluate training and/or competition loads. For that purpose, we should establish a training monitoring cycle like the one we can see in the next figure.

Figure 21: Athlete´s monitoring cycle



Source: Gabbett, et al., 2017, p. 1452.

According to the figure: which would be the first monitoring stage in this cycle? Knowledge of the physical demands or external load. In the first place, we should assess how much our players run, how tall they jump, at which speed, etc. Then, we should know the internal response to the proposed physical demands in each of our athletes. In a third step, we should know our players´ wellbeing, e.g. how they feel. The fourth and last step would be to know the player´s readiness for the next stimulus that could be training or competition. Anyway, this monitoring process should not end up here, but there has to be a connection between this last step and the previous ones. This connection is reflected in each of the quadrants (A, B and C), so that it allows us to make practical decisions for the management of next stimuli. This way, there exists a connection between the internal load and the physical demands players support. For example, when receiving a high external load and a high internal one, what is the message we should interpret and what decision should it entail? The answer is simple; we should lower the training load for the next stimulus. However, if we have a high external load and a low internal load response, it is a good adaptation of the athlete to the proposed stimuli. Now if we talk about a low external load and a high internal response, it is a maladaptation to the training loads. Lastly, if we see a low external and internal load, we surely have to increase training loads. This way, we could continue with each of the blocks that we have proposed in this cycle for monitoring the athlete. It is worth saying that the readiness for stimulus, which is the last step, can be skipped many times and we can go from the third to the first one.

We are going to focus on external load or, as we have said, on physical demands. Monitoring sport movements has been, since a long time, a task of interest especially for sports scientists like Carling, Bloomfield, Nelsen and Reilly (2008). Nowadays, luckily we can say that coaching staffs are using more scientific evidence in order to optimize performance and injury prevention, taking information from different means, like monitoring athletes´ physical demands. This way, these last years, sport sciences have evolved, especially, thanks to technological advances that have taken place in different fields. Therefore, trainers are becoming important and relevant characters inside the interdisciplinary work of the coaching staff. One of the trainers' main goals together with the rest of the coaching staff is to achieve and keep an optimal state of the team fitness condition during most part of the competition.

That way, there are three main variables that define team sports events, whether indoor or outdoor, and they will have a direct effect on physical demands. playing period, the space in which it occurs and the amount of players in that task. All this will condition physical demands that are produced by the task and/or the training situations that we will present to our teams or players group. These variables will generate, also, certain physiological responses that will demand the athlete adaptation, mainly reflected in their conditional structure. Physical education may lead this adaptation to adjust to the different requirements that each of the competitions demands, according to the disciplines in which athletes participate, like football, basketball, hockey, rugby, etc. and depending also on the competition system, the own play model, on the position of each player and on the competition level of the team we are working with. Anyway, certain external load levels could be related with an increase in probabilities of suffering injuries. These aspects must then be taken into account and they will be dealt with later on.

In order to monitor external load or physical demands, there are mainly three methods: systems based on video camera with an optical sensor, the IMUs and the positioning systems, either local or global. These 3 systems are included in the EPTS (Electronic Performance and Tracking System) concept. The EPTS concept includes technologies used in monitoring the individual and group performance in sports.

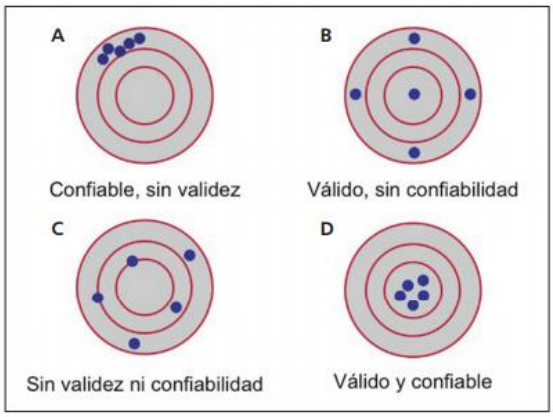
Before advancing with the three systems mentioned before, we should highlight a very important aspect to take into account in these moments in which technology is providing a lot of advances. Currently, we can make measures with biometric devices attached to the players´ head; they measure connections between different people, with cams, with smart watches, with devices on sport clothing, etc. Everything is possible thanks to applications that allow us to manage data.

Figure 22: Wearable technology

Source: Piwek, Ellis, Andrews y Joinson, 2016. p. 2.

For you to see how significant these technological advances are in the world of sports, in the year 2018 it was estimated that these devices and applications were used by potentially 119 millions of people. But these advances bring about very important things to which we must give priority. We are talking about the accuracy that should be shown always on the channels to get data for analysis. Thus, there are two essential concepts in relation to obtaining data and their analysis: the validity and the reliability of everything we measure. In fact, for example, only 5 % of applications technologies used are certified. That is why we have to be very strict and critical in selecting information que will use to make measures. This way, as we can see in the graphic, there are systems that are neither certified nor reliable, systems that are certified but not reliable, systems that are reliable but not certified and systems that are both certified and reliable.

Figure 23: Example of certification and reliability



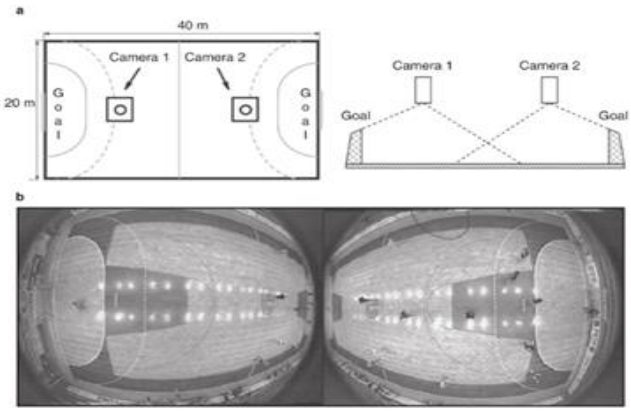
Confiable, sin validez	Reliable without validity
Válido, sin confiabilidad	Valid without reliability
Sin validez, ni confiabilidad	Without validity nor reliability
Válido y confiable	Valid and reliable

Source: Mantetola et al., 2018, p. 681.

Let's see an example. I step on the scale and the number is 68 kilos. I step out. Immediately, I step on the scale again and the number now is 80 kilos. Clearly, this device is not reliable. For it to be certified, we should compare it with the gold standard that grants certification, of the scale in this case.

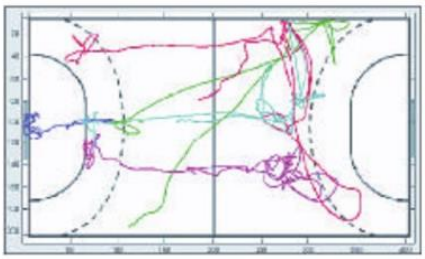
After this brief insert, let us focus on the 3 monitoring systems for physical demands already discussed. That way, for example, in Barris and Button (2008) publication they use two cameras on the hall ceiling to analyze locomotor actions athletes did during the match (figure 24), and they gave us information about the paths of each one of the players (figure 25), in every moment.

Figure 24: Monitoring by video cameras



Source: Barris y Button, 2008, p. 1035

Figure 25: Visualization of spacio-temporal paths

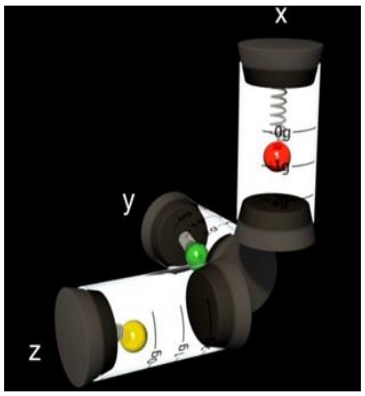


Source: Barris y Button, 2008. p. 1034.

Systems based on using inertial measurement units are, basically, the systems that are made up by accelerometers, gyroscopes and magnetometers. Accelerometers are devices that measure lineal acceleration, gyroscopes measure angular speed and magnetometers give information about magnetic north.

With these three sensors, we could study movements on flat or on space, according to the amount of axes that these devices have.

Figure 26: Inertial measurement units and movement axes systems



Source: [Untitled image of inertial measurement units and movement axes systems]. 2012. Recovered from https://www.woratek.com/category/tecnologia/page/22/

An important point to highlight when we refer to inertial measurement units is to point out a variable that is present, generally, in scientific literature and which is known as player load. This variable is represented by the square root of the summation of the difference of instantaneous accelerations squared, as it is seen on the next algorithm.

$$Load = \sqrt{((Ac1_n - Ac1_{n-1}) + (Ac2_n - Ac2_{n-1}) + (Ac3_n - Ac3_{N-1}))^2}$$

In conclusion, all this provides us with a vision of the global movement that athletes have developed. Just as we have said, an accelerometer is a sensor that measures acceleration. This does not need to be equal to the acceleration obtained by coordinates (device change of speed in space and time), but it is the type of acceleration related to the weight phenomenon experienced by a test mass that is found in the device's frame of reference. We find different types of accelerometers: the simplest one is mechanical and it is made up of a mass and a spring inside a cylinder. When a force is pushed against a mass, the spring is deformed and, by Hooke law, we can get to know the force that was generated. Taking Newton's principle into account, we know that force is equal to mass multiplied by acceleration. As a consequence, we can also calculate acceleration. If we imagine, for example, that a person hit a golf ball with the same force that that same person pushes a truck, what would be the result? Well, the golf ball's acceleration will be very big and the truck acceleration will be very low. Thus, there are other types of accelerometers that are more modern, with a length inferior to a millimeter; they are

microelectromechanical accelerometers that also give us the information already mentioned.

As a way of sharing a personal experience, I consider important to tell what happened the first year I was in the first FC Barcelona basketball team. We used some devices that were based on inertial systems. These devices gave us a series of variables, like for example, the player load, which they (devices owners) called total loading.
The first thing I considered was the fact that I had to give information to the trainer about the type of training players were doing during the training sessions. As a consequence, I had to make sure that those devices were measuring what they said they were doing, e.g. if they were certified.

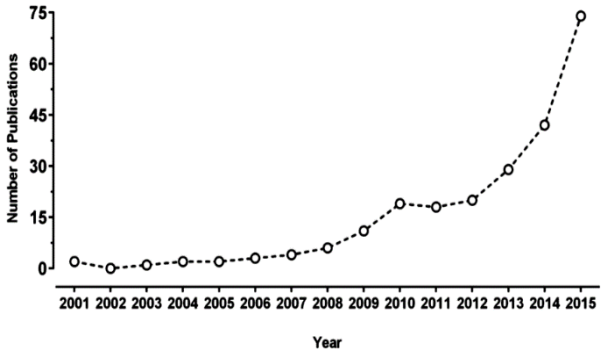
For that purpose, during warm-up exercises, I asked players to queue at the end line. Previously, I checked the length of the court. The activity consisted in running from one side to the other repeatedly and at different speeds. After knowing the distance and the time spent, I could also get the speed and compare it with the data the devices showed. That way I could really establish if the variables provided by the system were valid. For distance, for example, of the 28 m length, there were players whose devices showed 31 m and others showed 26 m. So if on a straight court we can have 5 m difference, in an hour and a half of training, what differences may appear? Interesting information, especially when you can transmit the trainer something that does not correspond to reality and that can lead the trainer to make mistakes in relation to the things the player is doing in the training sessions. That is why it is vital to have a guarantee about this type of information. Intra and inter units reliability was also analyzed.

Obtained data showed that measures were reliable.

In order to monitor physical demands, besides the video cameras with optical sensor systems and inertial measurement systems, the Global Positioning System (GPS) devices are used. GPS is a satellite-based radionavegation system established by the U. S. Department of Defense in 1973, although it took some more years for its complete implementation. It provides real time location of any object or person, either static or in movement, at any moment.

GPS is based on magnetic resonance that, in turn, is based on the atomic clock. Atomic clock allows us to have an extremely high precision on time control (Nicholson, 2015).
Researches on GPS usage and its control on physical demands or external load have increased exponentially, just as it is shown on Figure 27: it is still increasing nowadays.

Figure 27: GPS included on publications related to sport sciences



Source: Malone, Lovell, Coutss y Conroy Varley, 2017, p.19

We are going to make some comments about what is called GPS in different forums. Generally, GPS is used to refer to all the positioning systems, but not all of them are GPS. We could say that GPS is the American brand of the global positioning system. GPS is included inside the global navigation satellite system (GNSS) which is a satellite constellation that transmit a range of signals used for positioning and location in any part of the globe, either on earth, sea or air. With these devices you can establish geographical coordinates and a particular point altitude, as a result of signals reception from Earth artificial satellite constellations used for navigation, geodetic, transport, hydrography, agricultural purposes. Besides the USA GPS, there exists a global navigation satellite system (GLONASS) that belongs to the Russian Federation and it is part of the GNSS concept.

What advantages can we find in GNSS systems? Its installation is very quick. We simply need to connect the devices and it is not necessary to have an operator for control. What are the disadvantages? Although devices are small, it is still an element we have to attach to players' bodies during competitions we want to measure. It is still a handicap, especially in some sport disciplines in which it is not allowed. The other disadvantage could be the existence of some variables that might not be so precise, for example an acceleration that happens in a small amount of time might not be as exact as we expect. This was already proven by Buchheit and Simpson (2017) in one of its publications in relation to this topic. It is important to make it clear that there are more and more algorithms that help to minimize these types of mistakes.

Having said that, focusing on F.C. Barcelona, we will make a brief summary about the way using these satellite navigation systems has evolved in the club. This club was one of the first ones using these devices with GPS Sport brand, from the year 2011 until 2013. After that, Stat Sports brand worked in Barcelona from 2013 until 2017. And, finally, since 2017-2018 season, the Spanish brand Realtrack Systems with the well-known WIMU; they are the devices that are used in the whole football area, first team, Barça B, and in the rest of sport sections in the club, basketball included. One of the questions that we

should quickly ask ourselves is: Are there injury problems? Is there a risk when we carry these devices? In order to remove that possibility, the club, together with Doctor Daniel Medina and different trainers published an article in which we value all the hours our players had supported devices during a long period of time and we also detailed the amount of injuries or problems that appeared.

Tables 1 and 2: Study on possible security problems related to the usage of Electronic Performance-Tracking Systems

	FOOTBALL					BASKET		FUTSAL	HANDBALL
	Pro	B	U-19	U-18	Pro Fem	Pro	B	Pro	Pro
2011/12	0								
2012/13	0	0	0						
2013/14	0	0	0						
2014/15	0	0	0	0		0		0	
2015/16*	0	0	3	2	6	0	0	0	0
Rate x 1000 sessions	0	0	3,69	6,78	20,34	0	0	0	0

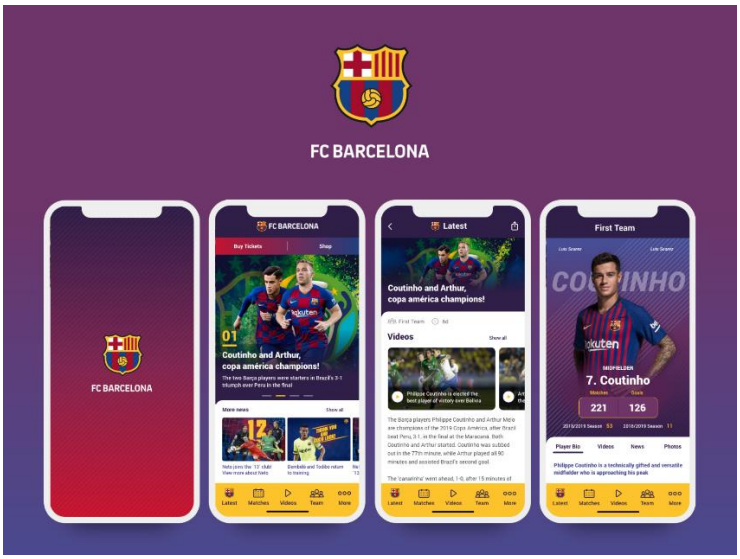
	FOOTBALL					BASKET		FUTSAL	HANDBALL
	Pro	B	U-19	U-18	Fem	Pro	B	Pro	Pro
2011/12	724,5	787,5							
2012/13	3053,25	3675	2852,5						
2013/14	3674,25	3990	3403,75						
2014/15	8955	3920	5092,5	2502,5		1164		1200	
2015/16* (until March)	2846,25	3500	2887,5	2660	1890	1140	1308	2328	180
Total	19253,25	15872,5	14236,25	5162,5	1890	2304	1308	3528	180
	56414,5					3612			

Source: Medina, Pons, Gómez Díaz, Vázquez-Guerrero y Camenforte, 2017, p. 29-30

No injury appeared. A punctual problem aroused in women football, mainly because the vest they wore was uncomfortable sometimes. In other words, we could practically reduce to none the problems in relation to the usage of this technology (Medina et al., 2017).

Another important aspect is to know what to do with this information. The first thing is to share it with the medical staff, with trainers and with players. To this end, the club created an application by which the first team football players received the information of the physical demands they had had in training sessions.

Figure 28: Official FC Barcelona application



Source: [Untitled image of FC Barcelona official application], 2019, https://bit.ly/34FzPpr

That way, we have seen that GNSS systems can be used in sports that are played in open fields like football, rugby, field hockey, but they cannot be used in basketball due to the impossibility of receiving satellites signals. This difficulty was overcome at the beginning thanks to the usage of systems with inertial measurement units and, currently, we have given a step further thanks to technology advances that allow the implementation of local positioning systems (LPS). Previously, we have talked about the GNSS systems (GPS and GLONASS) and now we are going to talk about LPS.

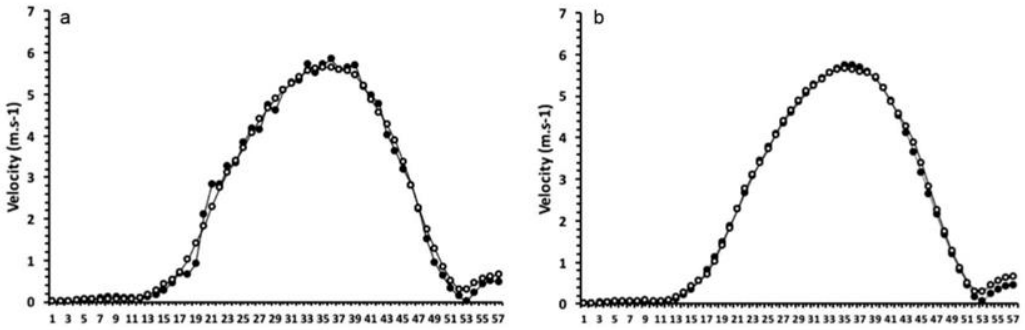
Nowadays, the club has already put some antennas on our hall that substitute the satellites in space and they allow us to know the position and location of each one of the players on the court. This way, the six antennas, which in our case are in Palau Blaugrana, emit signals that get to the receptors that players have attached at the top of their backs, installed in a vest. The system calculates the time necessary to receive that signal and, from there, it can have information about the location of the player on the court all the time by the reception of at least 3 antennas (triangulation).

Positioning systems provide us with different advantages, like their certification, reliability and their contribution with a great deal of information. In order to talk about disadvantages, we can mention its high cost. In the case of training outside our facilities where we have the fixed installations, the high cost would be for the portable antennas and for their location in each of the training courts.

As we have just pointed out, the first thing to do is to make sure that the LPS is a certified system when analyzing the published scientific evidence. In this direction, Serpiello (et

al., 2018) legitimize the functioning of these devices, taking the Vicon camera systems as a gold standard. They did sprints, displacements and changes of direction of 45º. Two different filter types were established for their analysis, not only for the Vicon system, but also for the signal system obtained by the LPS and, in both cases, a great validity was obtained (figure 20). As a consequence, the main conclusion, without further details, is that that study showed the validity of this system.

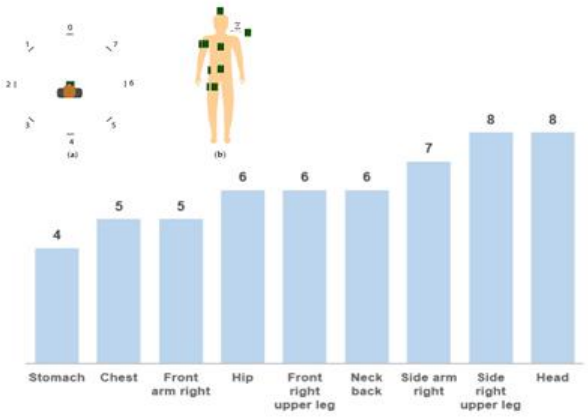
Figure 29: Vicon system validation with the signal system obtained by local positioning



Source: Serpiello et al, 2018. p. 1732

Another study in this same line shows a comparison, according to the location of the devices attached to the athlete. The elected parts were the head, the lower back, the upper back and the leg. One of the tests was to attach a device on a point and another one at a distance of one meter. An antenna was installed and the error in that distance was measured. The error in this case was very small, specifically of approximately 50 millimeters. Later, eight antennas were installed, a person stood among them and measures were taken again. Again the error was very small. Besides, we could observe the anatomic zone in which the best reception of the eight antennas was produced. This zone was the head; it showed a very small error in each of the signals received from the eight antennas. Later on, the person did a series of movements and the error was very small and, finally, different actions were done on the court and the result was again a minimum error (Ridolfi et al., 2018).

Figure 30: Comparison, according to the body place in which the devices are located



Source: own adaptation based on Ridolfi et al., 2018, p. 5.

In general, the average error in positioning estimations was of 20 centimeters and, therefore, these positioning systems based on ultra-wideband or UWB are valid and adequate to measure the dynamic athletic activities, e.g. for the athlete´s movements.

The last step is to copy the previously mentioned evidence to the devices we use every day. That evidence appears in a study in which the GPS and the LPS are compared, making three different movements: lineal, circular and zigzag sprints. The intraclass correlation coefficient was calculated and the result was close to 1, while the bias was very law, practically of 0, 0, 01, 0, 02 (Bastida Castillo et al., 2018). Data obtained prove the validity and reliability of the system we use in FC Barcelona, being even more precise than the GPS systems. This way, we can establish that the LPS error oscillates between 10 and 20 centimeters, whereas the GPS errors could be bigger (Bastida Castillo et al., 2018).

The LPS allows for real time data and its processing and analysis can manage a lot more information, once the session or competition is finished. We can also observe the tactical variables, as well as the load through the variables related to kinematics and physiology.

The variables we can find are based essentially on positioning. Firstly, position on X, Y and Z axes is obtained and, from there, speed, distance and acceleration, for example. The IMUs give us information about acceleration in G´s, the angular movement, the angular speed, the elevation and the player load.

When we connect with other devices, we can obtain heart rate and level of oxygen saturation by a device known as Moxy, the muscle electrical signals (EMG).

Which are the main monitored variables? In order to summarize, these variables can be grouped in three components: volume, intensity and density. The three of them are essential parts of the load. In relation to the volume, we can resort to total distance and to the player load. In relation to intensity, the high intensity speed >18 km/h, accelerations and decelerations higher than 2 m/s2, jumps (establishing the impulse and the landing separately). In this case > 3 G's or > 5 G's in landing and horizontal impacts bigger than 8 G´s.

In relation to tactical variables: what can we learn? Each player position, the zone in which he/she plays, the distance among players and the Voronoi map.

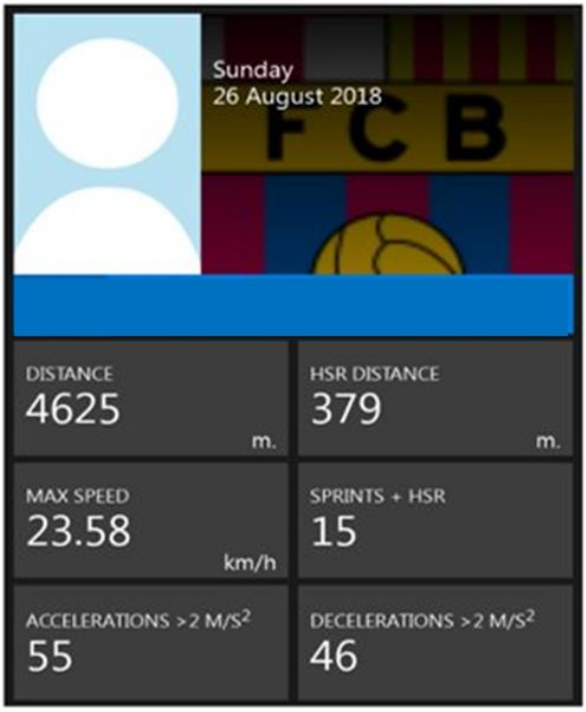
For interpreting data, we need to look at the total values. In other words, we have made 5 km in today´s session, but we should also look at the relative values to the maximum. For example, from the speed obtained in a concrete session, we should calculate the percentage it represents in relation to the maximum speed for that player, in order to have a more complete vision of what is happening and to adapt the load, as well. Besides, we should relativize data from physical demands, in relation to the total time of the session. For example, we have done 65 m/min in a particular task, which is going to be very different if the speed were 34 m/min in that same task or another one.

In conclusion, with the different systems presented, which are the three pillars that could help us to learn about the physical demands for the team training sessions and/or matches? The game model (which is a conditional demand), optimizing periodization/programming for daily and/or week training load, and relating it with performance and/or injury prevention and also helping in injury readaptation stage. In other words, if we know training or previous matches values before a training injury, it will be very easy to help in the player return to play process once he/she has suffered from an injury and, besides, it will allow us to adapt.

We can also monitor the differences among the playing periods, the different positions, the differences in categories according to ages, playing levels (elite or not) and among the ones who initiate a match or not.

We observe in figure 31 a brief report with six variables that we send to the players, so they can learn about their results.

Figure 31: Club report handed to the players



Source: own creation.

In this report we include the distance, the high density distance, the maximum speed, the number of times they have passed 18 km/h, the number of accelerations higher than 2m/s2 they have reached and the number of decelerations higher than 2 m/s2 they have reached in this session.

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