



**BARÇA**  
**INNOVATION HUB**  
Universitas

# **PHYSICAL DEMANDS AND INJURY RISKS TEAM SPORTS**

**Applying microtechnology to optimize  
performance in team sports**

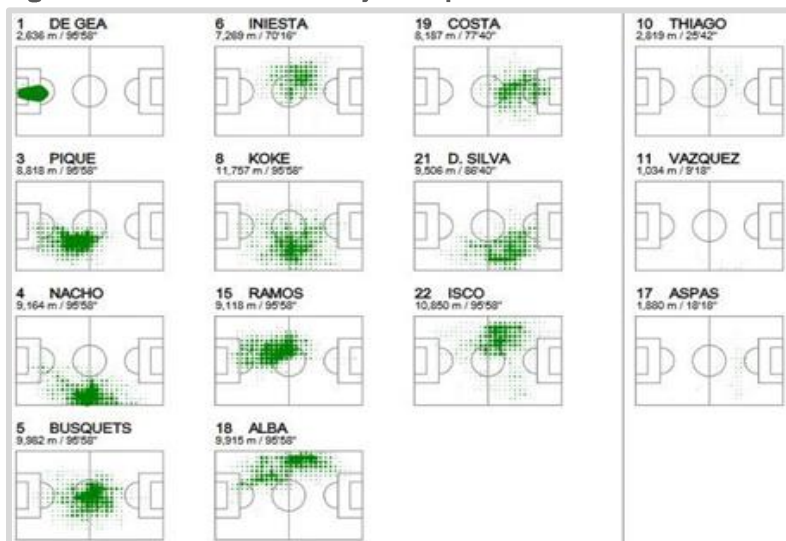
# Applying microtechnology to optimize performance in team sports

The main idea of this module, as the title reads, is to show the theoretical background and its practical applications that enables us to optimize performance in team sports through technological advancements. Achieving success in sports is usually a way full of difficulties and obstacles. In this way, when different teams win prizes, be it a Champions' League championship, an NBA ring or the King's Cup in basketball, it is because they are formed by high level athletes that have what it takes to get those prizes through their game.

The reach and relevance of technology in current sports are clearly reflected in the interest shown by the media through their headings in relation to technology. For example, in Spain the following headings can be read: "Barça covered 53,398 kilometres in 2017" (Sport, 2017, <https://bit.ly/2xv9spN>), "Dembelé raced in a sprint at 28.6 km/h, triple dribble and assistance" (LaLiga Santander, 2018, <https://bit.ly/2RFSnR8>), "Busquets, the one who covered the most kilometres, and Neymar as number three" (Solé, 2015, <https://bit.ly/3ejLoXD>) and "Madrid has no staying power, they ran 11.6 km fewer than Tottenham" (De la Riva, 2017, <https://bit.ly/2KhS5eQ>).

We can see that video-recording systems as well as the inertial measurement units (IMU) and location-based systems have revolutionised the world of sports for the people who work there - athletes, coaches, physical trainers -, the media and the readers or spectators.

**Figure 1: Distance covered by the Spanish football team.**



Source: MARCA newspaper, FIFA World Cup Russia.

Figure 1 offers information about the Spanish football team that participated in the FIFA World Cup 2018, in Russia. In these data we can see that one player, Koke, covered 11.7 km during one of the

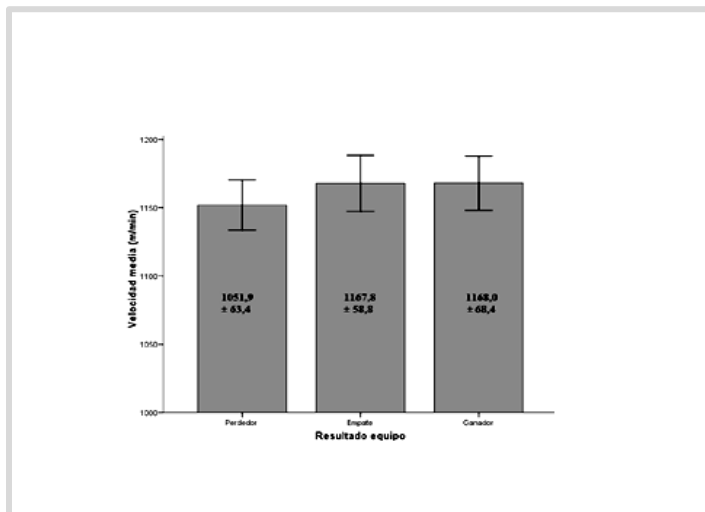


matches. We can also appreciate the areas through which each of the players moved - colour map. There is a great difference between a goalkeeper and a forward, or a center mid-fielder and a winger. These types of devices, systems which use IMU, or global or local location-based systems, are being used across different sports - be it basketball, football or handball.

For most of the teams, like Barcelona FC, winning prizes is their main objective; that is, achieving the highest sports performance. So, in what ways can these devices help us achieve this objective? Can we guarantee that the team that runs the most is the one that wins? The following is a very clear example: When teams lose, it is often said that athletes are not running, that they are late in each play, and so the conclusion is that they are not in shape. On the contrary, when teams win, this perspective completely changes, and it is said that athletes run a lot, that they are there before their opponents, and that they are in good shape. However, on the basis of the scientific literature that deals with these topics, as well as my persona experience, I consider that the previous assumptions do not correspond with reality at all.

The performance during a game depends on many factors, of which the tactical model, whether you play at home or away, the moment of the off-season when the game takes place, the score during the game and the opponent are some examples. For instance, Casamichana and Castellano (2014) analysed the physical demands and the scores of the different matches during the World Cup in South Africa, in which the Spanish team was victorious. In Figure 2 we can observe that there were not any differences in the distances covered by the teams that lost, the ones that tied and the ones that won, which means that the distance covered does not have an impact on the results.

**Figure 2: Average speed of movements made by teams that won, teams that tied and teams that lost during the World Cup in South Africa 2010.**



Source: Casamichana, 2014, p. 610

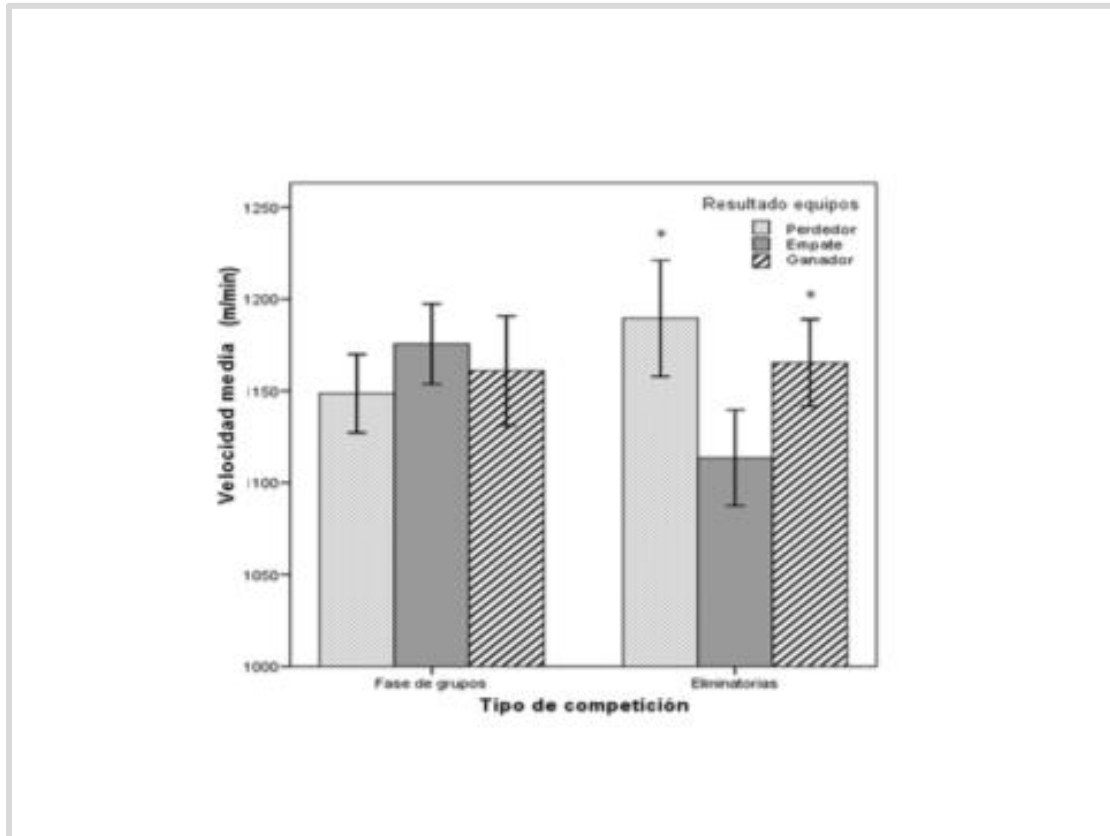
Velocidad media= Average speed  
 Perdedor= Loser  
 Empate= Tie  
 Ganador= Winner



Resultado equipo= Team result

And if we look at Figure 3, we can see that in the qualifying round there are differences in favour of the teams that lost, that is, the teams that lost were the ones that ran the most.

**Figure 3: Average speed of teams' movements in the different phases of competition in the World Cup in South Africa '10.**



Source: Casamichana, 2014, p. 611

Resultado equipo= Team result

Perdedor= Loser

Empate= Tie

Ganador= Winner

Velocidad media= Average speed

Tipo de competición= Phases of competition

Fase de grupos= Group phase

Eliminatorias= Knockout phase

The research mentioned before has been recently ratified by a very interesting publication carried out with all the football teams of the Spanish league, both the First and Second Division (Gomez-Piqueras, Gonzalez-Villora, Castellano, and Teoldo, 2019). The authors analysed physical demands through



three variables: total distance, distance to high intensity and distance to very high intensity; also, they divided the teams in two categories: one that included those on the upper half of classification, and another that included those on the lower half of classification.

**Figure 4: Values of the physical demands of teams on the upper and the lower half of classification.**

Physical variables	Upper half of classification	Lower half of classification	p	ES
				Cohen D
<b>First Division</b>				
TD	108,823±2,653 m	109,924±1,866 m	0.29	0.48
DHI	2,987±199 m	3,049±126 m	0.42	0.00
DVHI	2,853±192 m	2,885±139 m	0.67	0.00
<b>Second Division</b>				
TD	107,744±1,970 m	108,625±1,788 m	0.28	0.46
DHI	2,839±175 m	2,799±139 m	0.55	0.00
DVHI	2,656±273 m	2,569±187 m	0.38	0.00

*TD: Total distance; DHI: Distance to high intensity (21-24 km/h); DVHI: Distance to very high intensity (>24 km/h)*

Source: Gomez-Piqueras, 2019. p. 5

We can see that on the First Division, the teams on the upper half of classification ran 108.823 meters. On the other hand, the teams on the lower half of classification ran a little more, 109.924 meters, to be precise.

As regards distance to high intensity, the teams on the upper half 2.987 meters, while the ones on the lower half ran 3.049 meters. Once more, the teams on the lower half of classification covered a greater distance to high intensity than those on the upper half. As regards distance to very high intensity, the same phenomenon is perceived: 2.853 meters covered by the teams on the upper half, in contrast to 2.885 meters covered by those on the lower half. These findings suggest that, even if the difference were not significant, the teams on the lower half made a greater effort than those on the upper half of First Division.

In the Second Division, the same pattern emerged. There was not any significant difference between the teams on the upper and the lower half of classification.

The authors of this study went a little further and co-related the physical demands to what they call “variables of success”: the the final classification, the score, the goals in favour and against of each team. There appeared to be no significant difference between the teams on the First and Second Division. There was no co-relation between the physical demands and the variables of success.

In relation to the media, “El País”, one of the most important newspapers in Spain, published the following: “Attention fans, do not ask your team to run if you want them to win” (Martín, 2019, <https://bit.ly/2yToQN4>) (Figure 5).

Figure 5: Headline of “El País” newspaper.



Source: Martín, 2019, <https://bit.ly/2yToQN4>

¡Atención, hincha!= Attention, fans!

No pidas a tu equipo que corra si quieres que gane = Don't ask your team to run if you want them to win

It is debatable whether this headline is provocative or not, but we can dig deeper into it in order to understand the relationship between physical demands and success in team sports. The article shows a football-centered research. The results of that research show that victories in football matches are not achieved by running more than your opponent. In fact, the team which ran more meters usually lost. This is not new for us; we have noticed exactly this in two publications whose conclusions point out in the same line. Apart from these findings, the amount of ball-possession time did not appear as a conditioning variable; it had an impact on only 5% of the end result. Surrounding the box or pushing better on the opposing field do not guarantee victory, either. Due to this reason, LaLiga and other clubs' researchers and analysts who participated in this study have established a series of advanced metrics through which they are able to explain the reason why a team suffers a defeat or ends up victorious.

Not long ago, sport researchers focused mainly on analysing the physiological aspects, that is, how certain variables, such as heart rate, lactate and energy expenditure behaved through matches. Nowadays, there are thousands of metrics that reflect physical demands, which has allowed for a better scientific understanding, which goes beyond these physiological aspects. Media Coach company tried to find the way to quantify the real value of strategies; they looked for the tactical DNA of teams through data achieved through different analyses. This involved objectifying in quantitative terms, that is, quantifying the model of play, to find out how to improve efficiency by applying each one of these terms in a better way. One of the data that the analysis published in the newspaper revealed was the average distance that teams covered, which was 109km. The worst classified team ran 112 km, while the best classified, which at that time was Barcelona, covered only 103 km; there was up to 9 km of difference between the first classified and the last one. But, what about ball possession? The average number of passes on average teams was 14. The worst team only made 10 passes, and the best team, which once more was Barcelona, made an average of 18 passes.

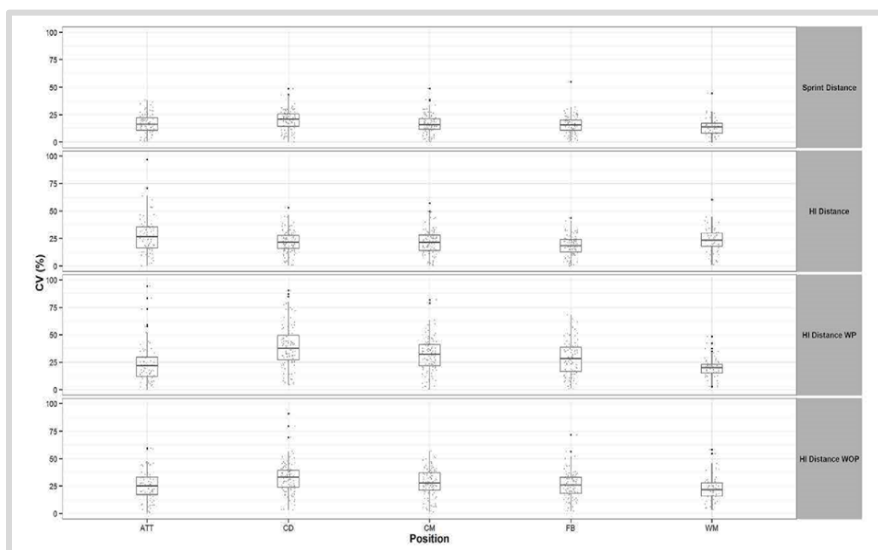
If we continue on our analysis, is there a relationship between how much we run and how much our opponent runs? The answer is “yes, there is”. Clearly, how much we run is conditioned, up to a certain extent, by how much our opponent runs.

We can assert that in a short period of time, how fit an athlete is barely fluctuates under normal conditions, that is, without enduring any excessive effort that surpasses the training workload, and thus, without a level of fatigue higher than the usual. In this sense, an athlete's highest speed will probably remain the same or be very similar today, tomorrow, in three days and in a week; and the same will apply for their highest degree of oxygen consumption, which will keep similar levels on the short term. However, the scientific literature available allows us to assert that the distance to high speed covered in different elite football matches played in a short period of time may vary up to a 30%. This means that the variation rate in the distance to high intensity covered in different matches may be up to 30%. What does this mean? It means that there is not an important relationship between an athlete's physical condition or conditional structure and that efficiency variable (physical demand) that occurs within competition.

In basketball we can also assert that the distance to high intensity covered in different matches may broadly differ (unpublished data). High variation rates were observed (near to 30%), which shows that the same behaviour may occur in both sports. Attention must be paid when relating, in a direct and lightly way, sports performance measured through physical demands to the team's and players' physical condition in competition.

Another research paper published in the Premier League analysed 451 matches in the time lapse that goes from 2005 to 2013.

**Figure 6: Variation rates in physical performance parameters according to the players' positions.**



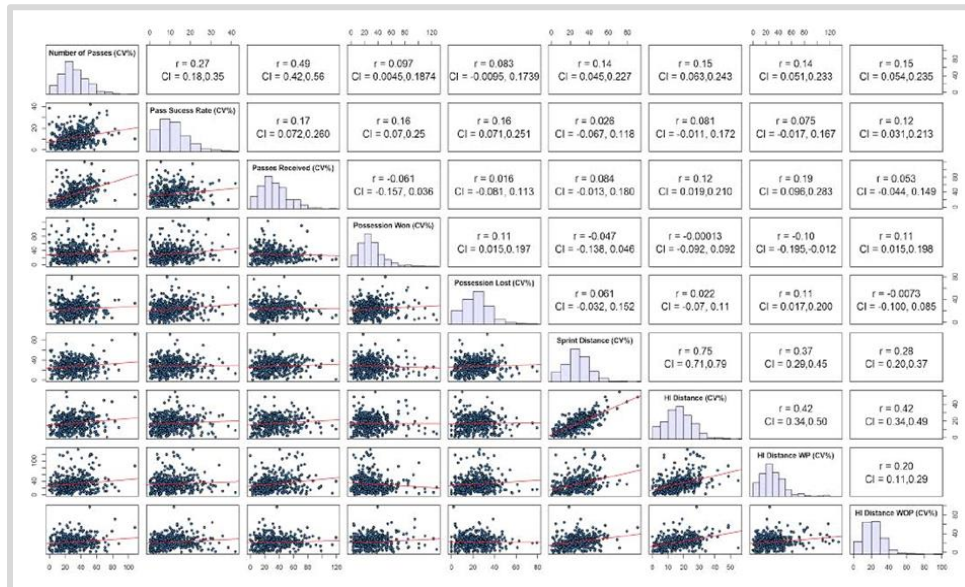
Source: Bush, Archer, Hogg and Bradley, 2015, p. 867.

What was the research about? It studied the relationship between the physical demands and the technical variables produced. The researchers observed that the variation rates produced in the matches were around 20% and 30% - as we have already commented on and justified with other



research papers in relation to the Sprint variable or the distance to high intensity variable. They also analysed, for example, the total number of passes, the number of successful passes, the number of attacks with direct one-on-one confrontation, and they once more found high variation rates. Technical parameters varied more than physical demands. On their part, the defence showed higher percentages of variation rates for offensive techniques, while the opposite occurred for offensive players, who showed higher percentages of variation rates for defensive techniques. They did not find a linear co-relation between the physical demands and the studied technical demands.

**Figure 7: Correlation matrix between physical and technical variation rates.**

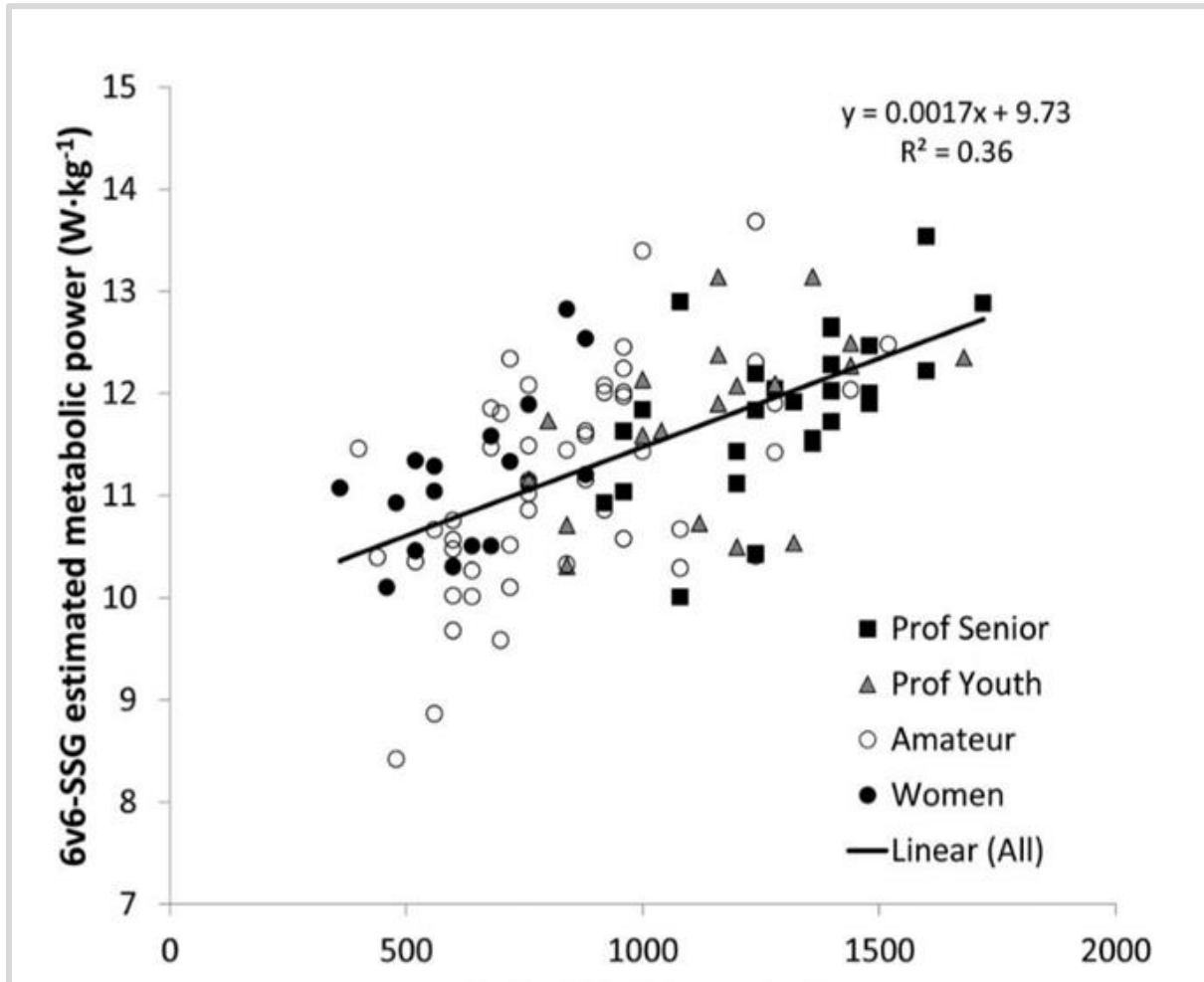


Source: Bush, et al., 2015, p. 870

We can conclude, then, that physical and technical demands studied in the aforementioned matches are variables that may change depending on the context. This shows the influence of contextual factors on collective sports.

There are other aspects dealt with in scientific literature which may also have practical applications. In football, the performance of a reduced game task, in which six players faced other six, was studied in order to establish the relationship that may exist between the physical condition of the players who performed that task, and the task itself. (Stevens, De Ruiter, Beek and Savelsberghet, 2016). All the players took a resistance test through the Yo-Yo Intermittent test. From the results of that test, the correlation with the metabolic power -physical demand got through microtechnology devices - was established and calculated. This was all applied on women, young men and senior football players.

Figure 8: Scatter-plot between estimating metabolic power in a reduced game six vs. six and the distance in the level two Yo-Yo intermittent recovery test



Source: own adaptation on the basis of Stevens, et al., 2016, p. 530

It can be distinguished how, in the same result in the Yo-Yo test, two players present very different metabolic power demands in the six vs. six task, as you can see in Figure 8: red and green circles. Clearly, the effort made by these two players in the reduced game task did not relate to their resistance level shown in the Yo-Yo intermittent test.

We can establish, then, that neither competition nor reduced game tasks are useful as tools to assess the physical performance or wrongly called, a player's "physical condition". It is impossible to determine our players' physical condition through observation or knowledge of their performance in game situations, be them training or actual matches. Therefore, it is essential to demystify the statement that we are physically unwell if we only value the results of the physical demands obtained in matches.

On the contrary, it is important to consider all the contextual factors that may directly influence, to a greater or lower degree, the physical demands required in a match. Coaches should understand that



through technological advancements, we can have access to valuable information to understand the relationship between the physical condition or shape and the physical performance or a given match result. This may really help us in our own performance as physical trainers.

Another contribution was provided by a publication by Martin Buchheit. Buchheit analysed running performance in football and the match result; he measured the distance that was run at more than 14 km / h during a match and identified two groups. On the one hand, he analysed the distance covered 5 minutes before a goal was scored, and on the other hand, the distance covered 5 minutes after a goal was scored. He used different categories: when a team conceded a goal and was losing, when it scored and was losing, when it conceded a goal and it was tying, when it scored a goal and it was tying, when it conceded a goal and it was winning and when it scored and it was winning.

What was the conclusion? The results showed there was no difference between the distance covered during the 5 minutes previous to scoring a goal and the distance covered in the rest of the match - except when the team tied; then, a slightly larger distance covered was appreciated. The conclusion was that distance does not appear to be an indicator of the success in a match, at least in this research. The reason for this is that there was practically no difference in the distance covered. The distance covered in the 5 minutes after a goal was scored was also analysed and compared to the average distance covered during the rest of the time in the match. There were differences in the distance covered in practically all the categories that we have previously mentioned. And it is possible that after conceding or scoring a goal, teams tried to re-organize themselves and to keep possession, which means that they ran less once scoring or receiving a goal. Lastly, another aspect that this article considers is: the greater the scoring difference on the scoreboard, the smaller the distance covered. This means that when facing wide scoring differences, teams tended to run less.

On the basis of the data provided by Casamichana and Castellano (2014), who compared the distance covered by all the teams in the Spanish football league when they had ball possession, and the distance covered when they did not, we can confirm what the authors assert: "Tell me how much you run and I will tell you how you play with the ball in play" (Casamichana and Castellano, 2014, <https://bit.ly/2Vrk55b>). All these data are useful to see that Barcelona FC, the winner in that league, was the one that differentiated the most from the rest of the teams in relation to the distance covered, both when they had ball possession and when they did not. The authors also showed the standard deviation of the results analysed and they tried to tackle the saying that goes "tell me how different the players run and I will tell you how they play" (Casamichana and Castellano, 2014, <https://bit.ly/2Vrk55b>).

We will see an example of one player in particular. We analysed data such as the minutes that this player played in different matches, the scores he got, percentages and his efficiency. We established two phases: one in which his performance was high, and another in which his performance was low. During the first phase, the media proclaimed that this player was performing at a very high level and that he was more than fulfilling the expectations of his signing. After some time, this player's performance evidently decreased. When facing more or less the same minutes of play, he would reduce his efficiency and the number of scores of the matches that corresponded to another stage of the season. In this second phase, the media heading proclaimed that the player was physically unwell.

We analysed all the training sessions of this player in both phases, with the use of microtechnology. We could not appreciate any difference in the two phases for any of the variables we were analysing: neither on the distance analysed nor on actions to high intensity, on the maximum speed or on this

player's maximum acceleration. There were not found any differences in the physical demands that this player performed during training session in both phases; however, there were changes in his performance during the match (Figure 9).

**Figure 9: Performance of the basketball player, through the use of official statistics**



Source: own elaboration

Rendimiento= Performance

In the following section we are going to deal with a very recurrent issue related to performance during competition in collective sports: fatigue. Paul, Bradley and Nassis (2015) conducted a research in the Premier League in which they compared the performance by means of physical demands - distance covered - during matches. The authors analysed if fatigue - considered in different articles as the possible cause of the decrease in physical demands during the first and the second part of a football match, or the first and the last period in basketball, and associated to a reduction in the distance covered in the two parts of football matches - is the cause of this decrease due to physiological factors.

They posed different questions: Does mental fatigue contribute to lowering the distance covered? The rhythm strategies that players consciously or unconsciously establish for different reasons during the match, may have something to do with it? The instructions provided by the coach to players or to the team may also have something to do with it?

Surely, the combination of the different concepts that appear above can better explain why these variations occur during matches. This is why we need to change the way in which we study fatigue in team sports. We must move from a reductionist analysis, carried out through a one-dimensional lens, to a more comprehensive one, analysing different factors at the same time, through a prism with different dimensions. In this way we will be able to understand what really happens and prove whether fatigue takes place or not.



In this vein, another article (Ryan, Coutts, Hocking, and Kempton, 2017) in relation to Australian football, shows an analysis of the variation in distance covered in different matches of this sport. The authors noticed that this distance was, in part, influenced by playing at home or away, the specific moment of the season, the match result and the opponent. The authors concluded that matches won with more player rotations and against a stronger opponent resulted in small or moderate increases in relative total distance, and that more interruptions occurred in the matches during the season, in comparison to the pre-season. Moreover, they concluded that away matches resulted in small or moderate decreases in relative total distance covered.

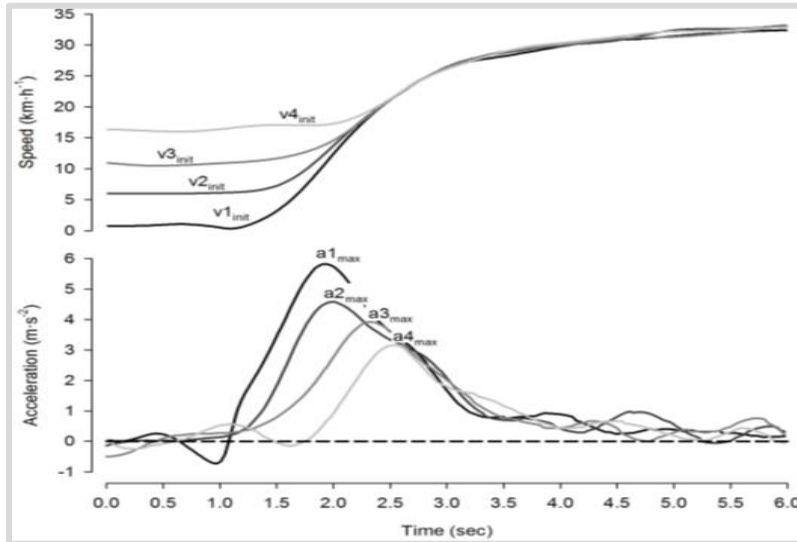
So, is physical training important? We will try to answer this question.

Zidane, in his first stage as Real Madrid's head coach, commented the following in one of his first interviews: "We need to improve in relation to the physical condition" (Medina, 2016, <https://bit.ly/3baFpCr>). Afterwards, the media portrayed their physical trainer racing around the field with the team, and doing exercises aimed at training the so called "core". In this way, the media supported Zidane's comment in relation to improving the team's physical condition.

If we continue analysing data in relation to physical condition, both Leo Messi and Cristiano Ronaldo are part of a selection of the 10 fastest players. Players such as Robben or Bale are also part of this selection. As we can see, some of the best players in the world do have at least some high condition capacities.

Another example is the comparison between one of the greatest sprinters of all times, Asafa Powell, and Leo Messi running five meters. The power that Asafa Powell generated was 476W, while Leo Messi got 378W. However, when it was relativized to body weight, the power reached by Leo Messi in those first five meters was 5.56 W, compared to Asafa Powell's 5.41 W. This shows Leo Messi's great acceleration capacity. We need to distinguish, however, that it is possible to accelerate in different situations. We can accelerate starting from zero or, as we see in Figure 10 and Table 1, we can analyse accelerations starting from 6 km/h, from about 11 km/h or from about 16 km/h; what will be the highest acceleration? The acceleration with the greatest extent will occur, of course, when starting from zero. However, when speed increases, the difficulty to accelerate also increases. However, metabolic expenditure is greater when we accelerate during the racing phase. We should keep in mind these data when analysing our players' physical demands.

Figure 10: Speed curves (above) and acceleration (below) of an athlete



Source: Sonderegger, et al., 2016, p. 4

Table 1: Speed and acceleration from different starting speeds.

$v_{init}$ (km·h <sup>-1</sup> )		$a_{max}$ (m·s <sup>-2</sup> )	$v_{max}$ (km·h <sup>-1</sup> )
Standing		6.01 ± 0.55 (5.88; 6.14)	31.3 ± 1.5 (30.8; 31.5)
Trotting	6.2 ± 0.8 (6.0; 6.4)	4.33 ± 0.40 (4.24; 4.43)	31.1 ± 1.4 (30.8; 31.4)
Jogging	11.4 ± 1.3 (11.1; 11.7)	3.20 ± 0.49 (3.08; 3.31)	30.7 ± 1.5 (30.4; 31.1)
Running	16.7 ± 1.2 (16.4; 17.0)	2.29 ± 0.34 (2.21; 2.37)	30.7 ± 1.5 (30.3; 31.0)

Source: Sonderegger, Tschopp and Taube, 2016, p. 5

Therefore, on the basis of the evidence shown by this research, we can conclude that high-intensity accelerations occur from 75% of each player's maximum acceleration, which corresponds to different situations:

- From 0km/h: > 4,51 m/s<sup>2</sup>;
- From 6km/h: > 3,25 m/s<sup>2</sup>;
- From 10,8 km/h: > 2,40 m/s<sup>2</sup>; and
- From 15 km/h: > 1,72 m/s<sup>2</sup>.

Using acceleration percentages avoid the bias of overestimating or underestimating accelerations that start with a slow or fast initial race. Furthermore, this percentages allow us to establish intensity thresholds that individualize this aspect.

In our own unpublished data, in which we analysed basketball tasks, we can indicate how, according to the established speed zones from 0 km/h to 1 km/h, from 1 km/h to 6 km/h, from 6 km/h to 12 km/h,

from 12 km/h to 18 km/h, from 18 km/h to 21 km/h, from 21 km/h to 24 km/h and more than 24 km/h, the highest number of high intensity accelerations occurred when the players started at 0 km/h. When they surpassed 21 km/h, we could not find any acceleration rate, neither to low nor high intensity. The opposite occurred when we analysed negative accelerations (decelerations). In the areas where speed was higher than 21km/h, there was the highest deceleration to high intensity percentage. In Figure 11 we can see the data of a basketball player during a game. The white line fluctuates and shows the player's speed, and the shaded areas show the moments when accelerations occur. The red lines correspond to this player's acceleration thresholds during the match at 3 m/s<sup>2</sup> and - 3 m/s<sup>2</sup>.

**Figure 11: Live graphical description of the speed and acceleration of a basketball player**



Source: own elaboration on the basis of RealTrack Systems.

If we analyse most of the actions that Leo Messi performs, we will see that his ability to accelerate and decelerate with the ball is very high. Therefore, we can affirm that the player's conditional capacities and, therefore, the physical preparation, are a very important factor, and it is in our hands to help our players, and complement all the technical and tactical work with the training of the conditional structure to try to optimize their play.

There are no doubts that physical training is important, but we need to differentiate certain variables, that is, quantity and quality. Also, we should not forget that there are variables, such as volume, that are related to quantity and that may have less impact, as we have already seen and analysed, for example, in the study of the World Cup in South Africa, in which there were no differences in the distance covered by winners, losers, or those who tied. Intensity, in turn, is related to quality.

This is the reason why, all the manuals on the theory of training, deal with intensity and volume. This can be related to the variables obtained through the use of WIMU devices, with neuromuscular aspects related to the sprint or to accelerations and decelerations greater than 2 m/s<sup>2</sup> or 3 m/s<sup>2</sup>. Volume, in turn, may be related to other variables provided by these devices, such as distance.

It is worth to point out that in many of the research papers mentioned in this course there are always linear correlations, but we should be careful when reading them, because, although they are useful, on certain occasions they may jeopardize achieving an understand of reality as it actually is. Thus, it is essential that we are able to carry out analyses on the basis of non-linear methods, as well as linear ones. To do this, we can use complex dynamic systems, which help us better analyse and understand what occurs in team sports performances. My proposal is to avoid analytical analysis of the physical demands that we obtain in training. However, this is not an easy task. El País newspaper once again shows who the best passer is, who recovers the most balls for each one he loses and who gives the most passes near the opposing box during the competition. We should relate all these data with the data provided by technology.

**Figure 12: LaLiga's best statistics**



Source: *El País* newspaper (<https://bit.ly/2ybPYqu>)

Las 13 estrellas mimadas por la estadística= 13 stars spoiled by statistics

Juega a adivinar qué futbolistas han sido los mejores de la primera vuelta= Play to guess which players have been the best in the first round.

Cada partido de LaLiga Santander genera millones de datos= Each match of LaLiga Santander generates millions of data.

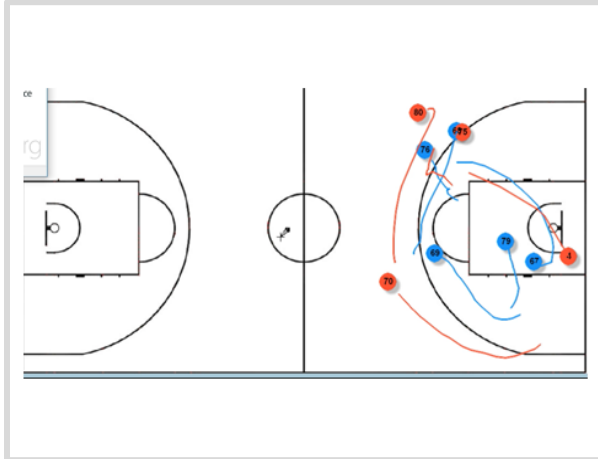
Todo se graba y se almacena= Everything is recorded and stored.

Del análisis meticuloso que hace el departamento de Mediacoach se extrae qué jugadores tienen mayor incidencia en sus equipos= The thorough analysis carried out by the Mediacoach department indicates who are the most influential players on each teams

In Figure 13 we can see data provided by LPS. The representation of different players performing a task in basketball can be observed. The lines that appear behind these players are the trajectories they have covered in the last five seconds.

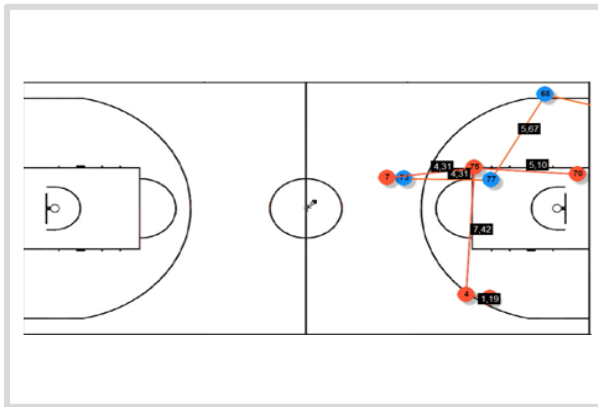


**Figure 13: Trajectories covered by basketball players during five seconds**



Source: own elaboration

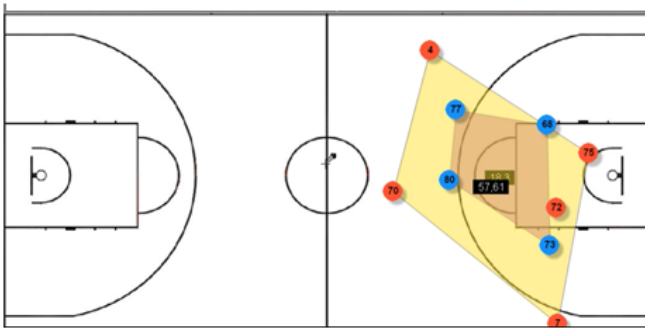
**Figure 14: Distance established among each of the players**



Source: own elaboration



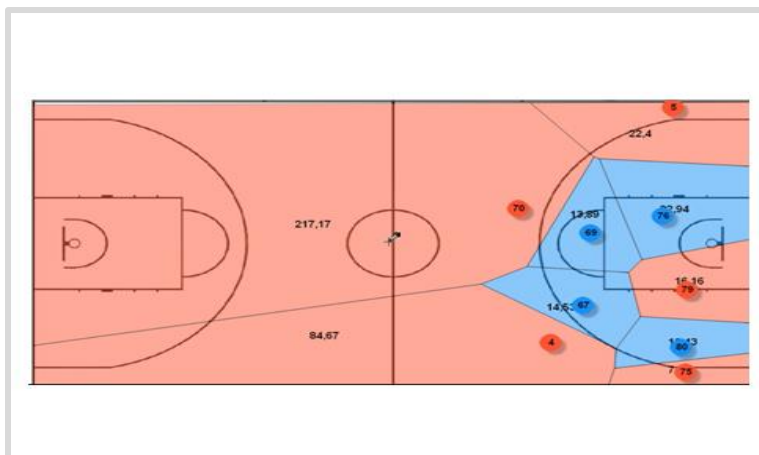
**Figure 15: Area needed by each one of the teams, shown in two different colours**



Source: own elaboration

In Figure 16 we can see the Voronoi map, which I previously cited as one of the tactical variables that can help us with our coaches. The map shows the area of influence of each player, that is, the area that player would reach if all the players ran at the same speed. This is a useful tool to show coaches and players, their "area of influence" in some system, such as the defensive one.

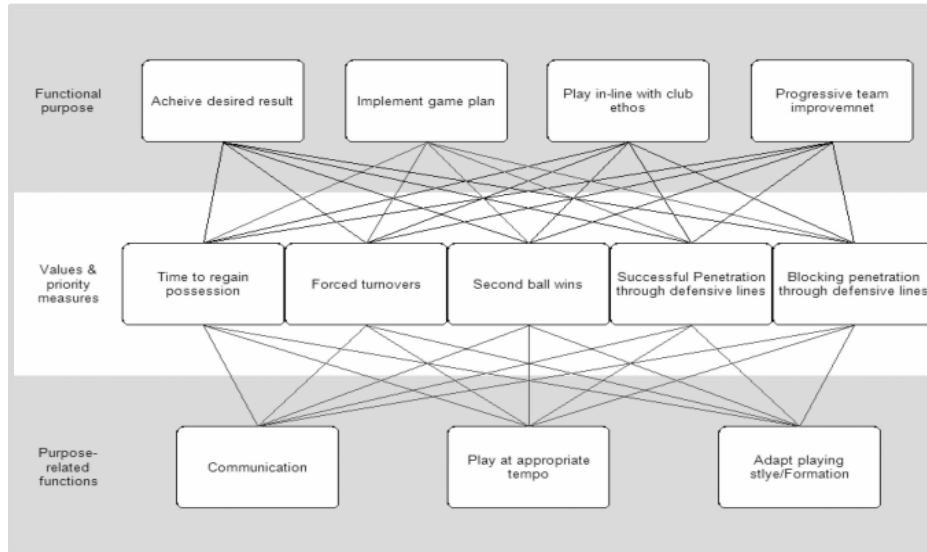
**Figure 16: Voronoi map**



Source: own elaboration

In Figure 17, the authors Mc Lean et al. (2017) show a method to analyse performance in football, on the basis of complex dynamic systems.

**Figure 17: Performance analysis**



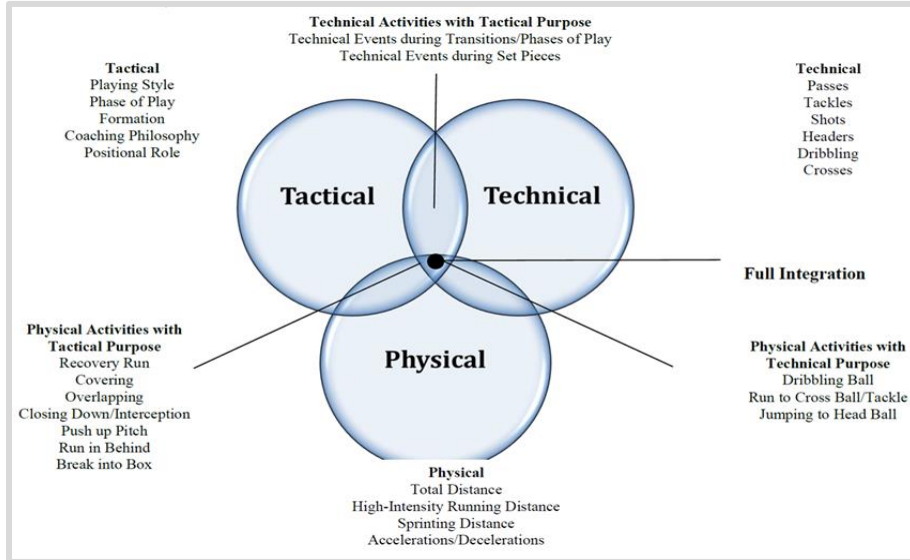
Source: Mc Lean et al., 2017, p.7

This diagram shows the first thing we need to know when understanding and analysing what occurs during matches. In the first place, the system's functional objectives must be established, that means, obtaining some kind of result. In the second place, the necessary criteria to measure the progress made in the process towards attaining these objectives must be agreed on (goals and ball possession, among others). Afterwards, the general functions of the system must be established, that is, what happens in attack, defence, transition, etc. In addition, both the physical functional capacities (kick, lead or run) and the physical components of the system (players, balls, referees, field of play, etc.) must be established. Establishing these components will result in a detailed description of the football match system. In basketball, we should change, for example, goals for baskets, kick for shooting, and any other element that we consider appropriate for basketball, so that the diagram finally adapts to our collective sport. The rest of the model helps us understand, analyse and interpret our performance in the game.

Along these same lines, a research paper by Bradley and Ade (2018) determines the relationship between conditional structure, cognitive or tactical structure, and coordinative or technical structure (Figure 18). The different tactical, physical and technical variables are established, and later related to one another (Figure 18). Then, a series of concepts is chosen, such as executing a cover, a counter-attack, moments when there was possession or when there was not.

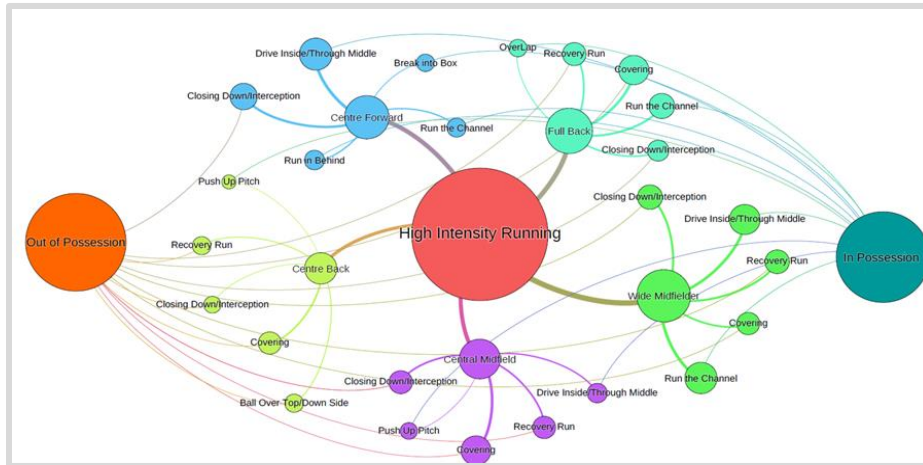
The most interesting aspect is the analysis of the distance covered to high intensity by the players, in the previously established context: first by positions and showing how those meters covered to high intensity were distributed in each of the previously selected tasks (Figure 19 and Figure 20). In a nutshell, how much they had run in situations such as a counterattack, or when covering, among others (Figure 20).

**Figure 18: Relationship between tactical, technical and physical variables in game situations**



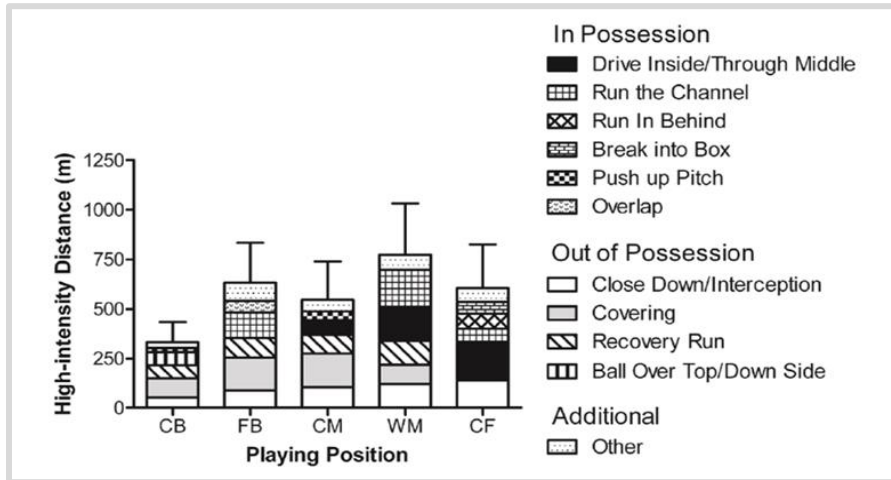
Source: Bradley and Ade, 2018.

**Figure 19: Application of the integrated approach to the specific positions of the game in football**



Source: Bradley and Ade, 2018.

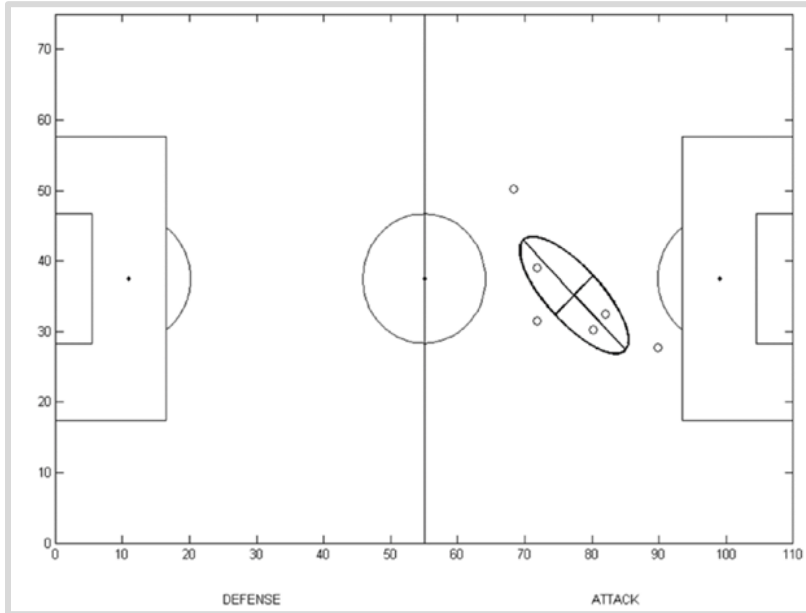
**Figure 20: Determination of the technical-tactical actions carried out during the race to high intensity**



Source: Bradley and Ade, 2018.

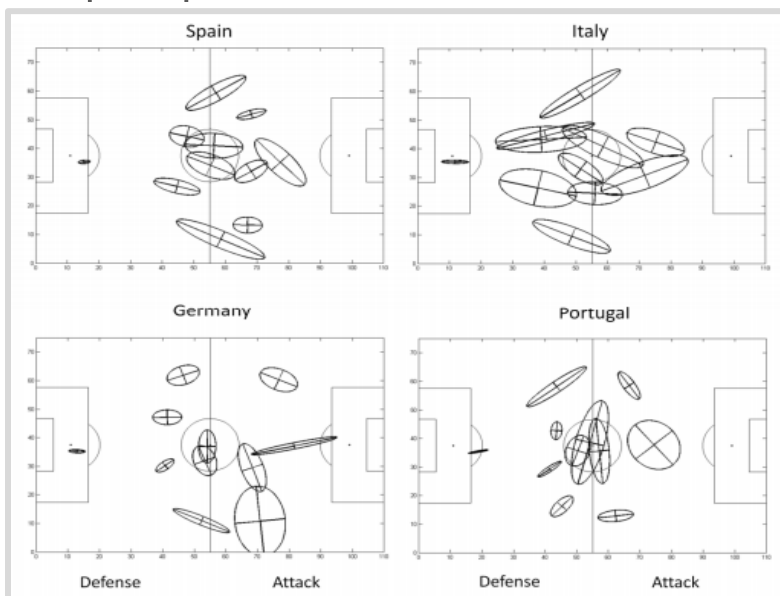
Previously, we have used variation rates to relate the physical condition, understood as the quantification of the physical performance (physical demands) with the external workload (physical demands) in game. Let us return to that approach, but now from another perspective. To do this, first we need to make reference to an article published by Moura, Santana, Vieira, Santiago and Cunha, in 2015. The average position of the players on the field was studied during six different games played at the football Eurocup, in which the Spanish team was proclaimed champion of Europe in 2012. In Figure 21 six points can be observed, which correspond to the averages of the matches, and the oval formed by the two axes corresponds to the variability of that average position. In order to get these data, a principal component analysis was performed, a statistical analysis that allows us to obtain this oval - this variability.

**Figure 21: Principal component analysis**



Source: Moura et al., 2015, <https://bit.ly/2XFnkPp>

**Figure 22: Principal component analysis on four teams during the 2012 UEFA European Championship**

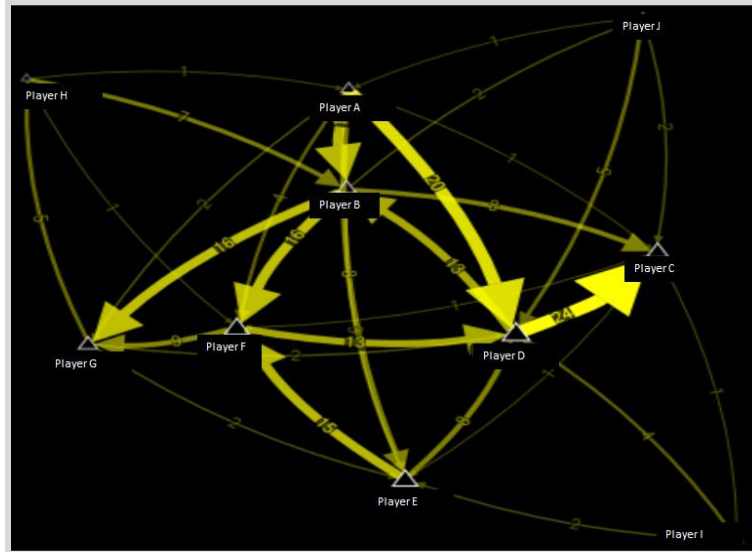


Source: Moura et al., 2015, <https://bit.ly/2XFnkPp>

The analysis was carried out on four national teams belonging to Spain, Italy, Germany and Portugal. Figure 22 shows the variability of the area for each of the playing positions. The results showed that the Portugal team exhibited the lowest variability, followed by Germany, Spain and Italy. The study



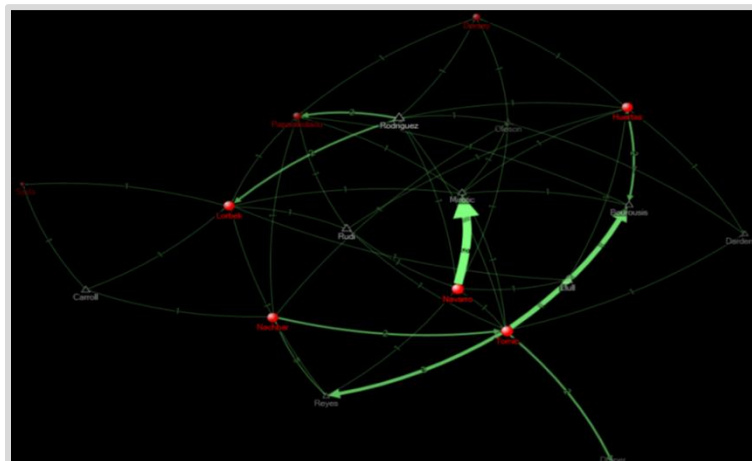
**Figure 24: Passes net of Real Madrid**



Source: Adapted from Cencerrado, 2014.

Figure 25 analyses the net of turnovers among teams. It can be seen that the greatest amount of conceded ball corresponds to Barça, especially by player G, due to missed shots, and player D, due to turnovers on ball recoveries, failures of assists and interior shots. In the case of Real Madrid, the only remarkable data is the case of player A, due to errors in external shots, transformed into turnovers to FC Barcelona due to defensive rebounds.

**Figure 25: Net of turnovers among teams**



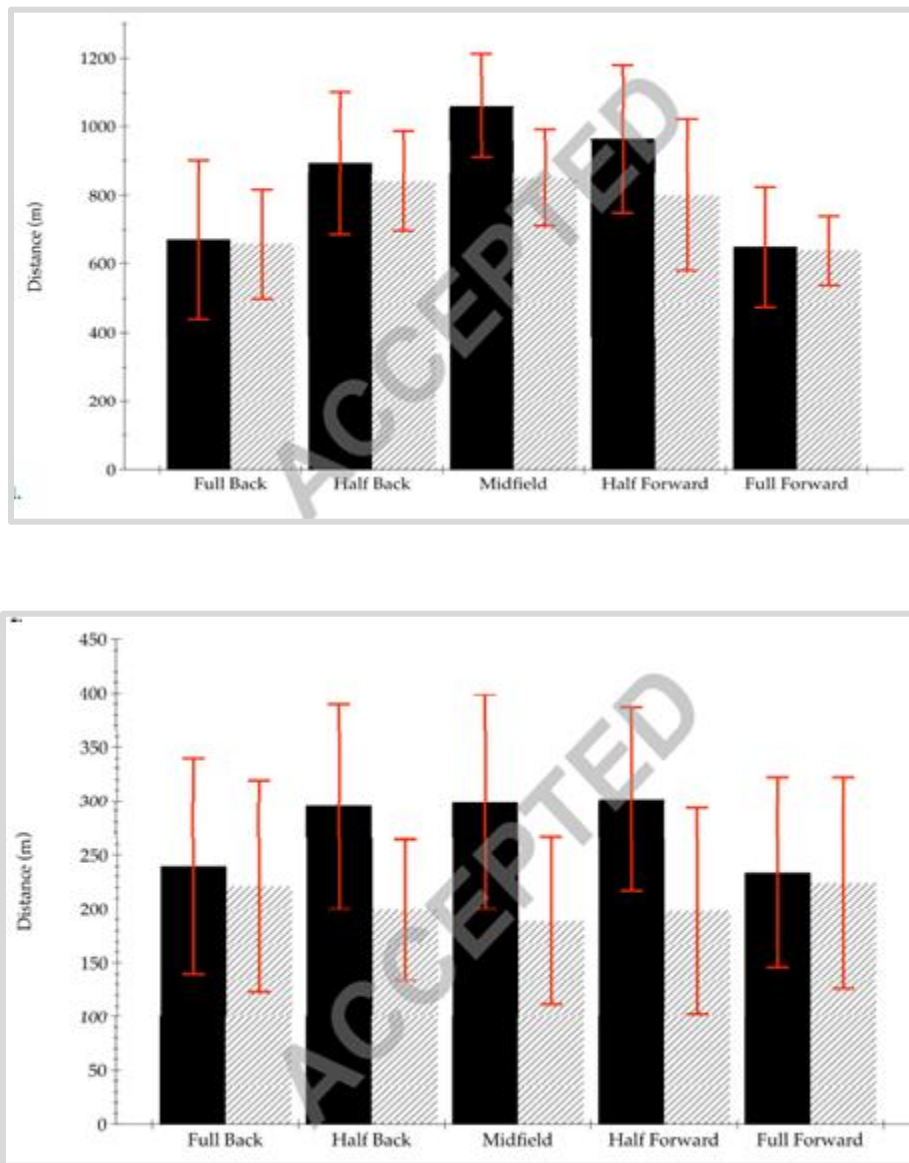
Source: Adapted from Cencerrado, 2014.

Up until now, we have always referred to physical demands in terms of average data, sometimes specifying them through playing positions. We have also pointed out the need to individualize the monitoring, assessment and interpretation of these physical demands - even if we have the data of



playing position. Figure 27 compares the distance covered at 17 km/h and 22 km/h in the first and second parts of Gaelic football. The analysed results showed that the differences in total distance, distance to high speed and sprint distance were significant among the different positions. The ones who ran the most were center-midfielders. This was the first study to show a detailed description of match performance during an elite Gaelic football competition.

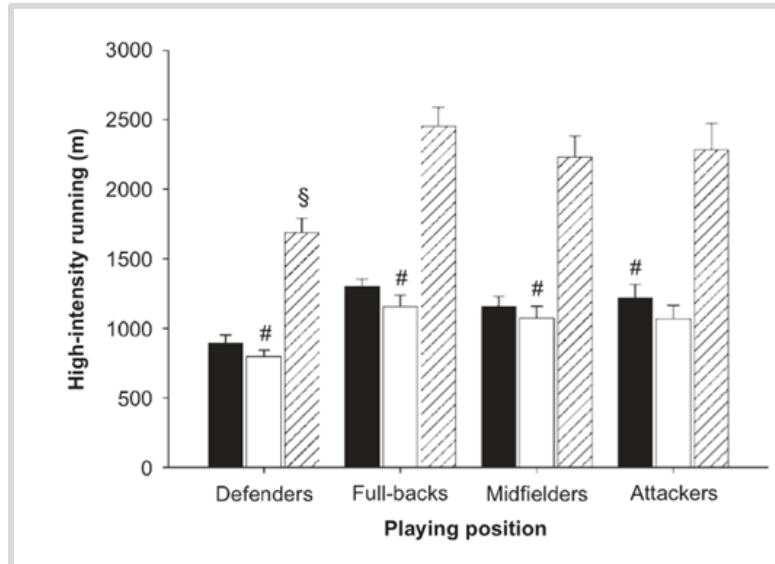
**Figure 27: Distance covered at 17 km/h and 22 km/h in the first and second part**



Source: Malone, Solan, Collins and Doran, 2016.

In Figure 28, the distance covered in football during the first and second part is shown, and the two are compared according to the different positions. Once more, there were outstanding difference depending on the positions observed.

**Figure 28: Difference on distances covered to high speed in different positions**



Source: Mohr, Krstrup and Bangsbo, 2003, p. 525

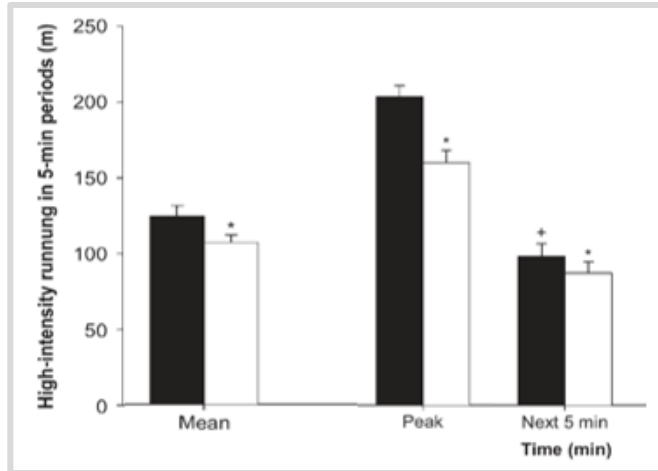
In team sports, on certain occasions, we push the conditional and bioenergetic structure to the limit. We can see it in some plays that require, for example, a great amplitude of movement, as well as different types of force expressed in a change of direction, in a powerful jump, and so on.

These episodes of maximum intensity or demand are frequently trained in the gym, through strength training, range of motion, using rotational resistance devices, vibrating machines or destabilizing material, in order to prepare the player for maximum accelerations and decelerations, high intensity changes of direction, landings, among other efforts that are typical of the game.

However, that is just part of the job. The other part is carried out in the training that takes place in the field and that we can measure through microtechnology devices. These allow us to monitor, control and assess, and in turn, optimize performance, establishing, for example, the number of accelerations and decelerations, the distance to high intensity, and the landings and impacts required by the competition.

This is how the most demanding scenarios come up. These are the moments of the match when at least one certain physical demand reaches its maximum peak. For a long time, we have dedicated ourselves to analysing the physical demands only by calculating the average values. In Figure 29, we see how the peak analysed in a five-minute football match is greater than the average of the distance covered in the average of those same five-minute intervals.

Figure 29: Comparison of the average and peaks of the stride to high intensity



Source: Mohr et al., 2003, p.525

These peak scenarios have appeared in the literature as "Worst case scenario" or "Most demanding passage".

In elite rugby players, different games were analysed and the moving averages of rolling average were used as a technique to come up with the maximum intensity scenarios. The first thing Cunningham, Shearer, Carter, Drawer, Pollard, Bennett, and Kilduff (2018) did was set up different time windows, 60, 120, 180, 240, and 300-second windows, and departed from there to perform the analysis.

**Figure 30: Comparison between the traditional and the adjusted method**

HSR (m·min <sup>-1</sup> )	Team		
	ROLL Method	FIXED Method	Difference %
60 s	54.3 ± 25.1*#	49.0 ± 22.4#	-10.9
120 s	32.6 ± 17.6*#	28.5 ± 15.5#	-14.4
180 s	25.0 ± 15.6*#	21.1 ± 12.9#	-18.6
240 s	20.9 ± 13.5*#	17.5 ± 11.1#	-19.8
300 s	17.9 ± 11.8*#	14.9 ± 9.1	-20.4
<b>Distance (m·min<sup>-1</sup>)</b>			
60 s	165.6 ± 22.3*#	148.1 ± 22.1#	-11.8
120 s	130.9 ± 17.8*#	117.9 ± 18.2#	-11.0
180 s	115.3 ± 16.5*#	102.8 ± 15.8#	-12.2
240 s	106.7 ± 15.0*#	95.5 ± 14.0#	-11.8
300 s	100.6 ± 14.0*	90.4 ± 13.9	-11.4

Source: Cunningham et al., 2018, <https://bit.ly/2xufya3>

We can observe significant differences between the analysis of each minute, based on the traditional averages, using fixed averages, or the assessment through the rolling average or moving averages. The moving averages in the different windows always reflected higher physical demands. Therefore, we propose a change in the traditional paradigm, based on the analysis of physical demands, either during games or training sessions, using traditional averages. To succeed in doing this, we need to analyse and interpret what happens to the peak physical demands or maximum demand scenarios that occur during training or competition and that should be the basis on which we train our players in order to optimize their performance in any team sport. Furthermore, we should determine the most important time windows to analyse the game in our sport.

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