Module 2. Inertial systems application for quantifying and interpreting physical demands in basketball

Unit 2.1 Inertial systems application for quantifying and interpreting physical demands in basketball

Knowledge about physical requirements in competitions and training sessions is relevant for optimizing the training process. At the same time, we have seen that the evaluation of physical demands by the analysis of movement with cameras cannot be used in everyday practice. In this module, we will take another approach for using technology that could allow us to make decisions through the analysis of data obtained not only in matches, but also in training sessions.

We know that in basketball accelerations, decelerations, changes of direction, jumps and high intensity sprints are physical performance maximum expressions. Therefore, the ability to repeat these patterns effectively will be essential when analyzing the player's state specifically.

This way, we can broadly differentiate four intensity levels in relation to the total number of game actions.

Table 1: Four intensity levels

Actions intensity	%
High intensity	13 to 21 %
Moderate intensity	11 to 28 %
Low intensity	14 to 26 %
Recovery	30 to 60 %

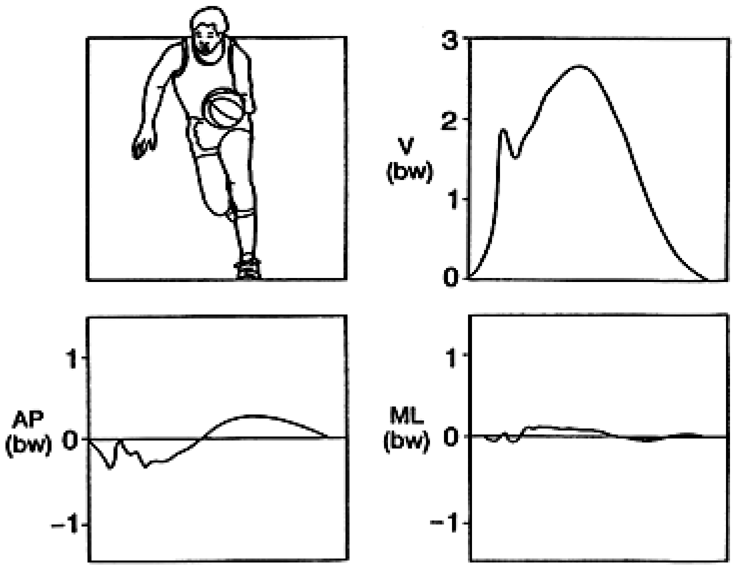
Source: own creation.

As we have pointed out, problems caused by analyzing time/movement by video analysis had led us to using inertial systems (WIMU). WIMU make reference to multisensors like accelerometers, gyroscopes, triaxial magnetometers or a combination of them. Generally, these devices are put inside a vest located in the players' upper back and they do not represent an additional load. Furthermore, they represent an alternative to GPS and, although they do not provide the same variables, they are indeed an alternative to the GPS used in sports, such as football and rugby, that is to say, outdoor sports. These devices take movement as load, combining immediate changes in acceleration in all of three movement planes. We should remember that satellite signals do not work adequately in an indoor field. If we introduce words such as accelerometer and basketball in search engines like Pubmed, different interesting publications will appear. In this module, we will make a summary of some of them.

Before going deeper, however, it is necessary to mention a publication titled *A Profile of Ground Reaction Forces in Professional Basketball* by McClay, Robinson, Andriacchi, Frederick, Gross, Martin, Valiant, Williams and Cavanagh (1994). The study results (produced in laboratory conditions and using a force platform) will be used for measuring and understanding the mechanical stress that body supports while doing specific movements in basketball.

In the next graphic, we can appreciate the impact produced in a forward sprint. We can observe a first peak and then a second one that appeared when the analysis with the force platform was made.

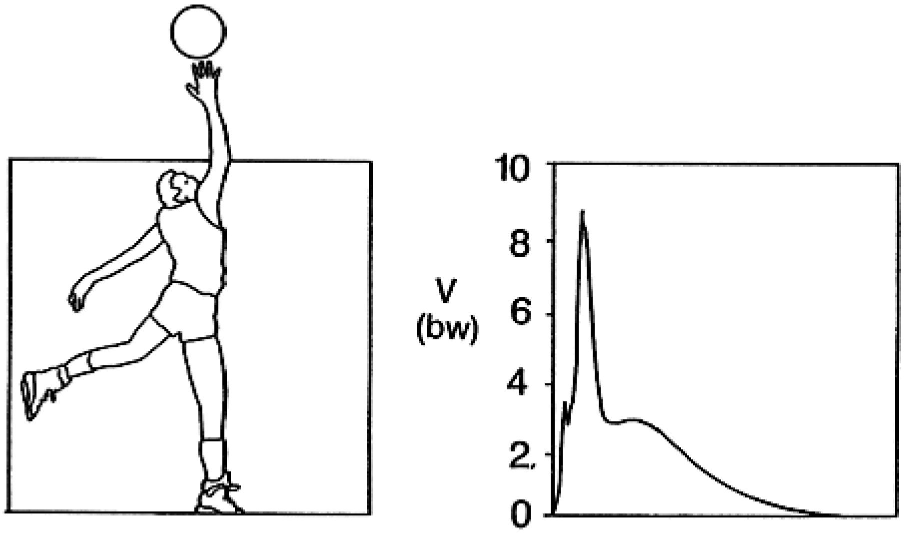
Figure 1



Source: McClay et al., 1994, p. 229.

In the study, they established the impact the player experienced in landing after a layup. In this case, the impact was of eight or nine times the player´s body weight.

Figure 2



Source: McClay et al., 1994, p. 230.

In a forward sprint, impact is not heavier than three times the body weight. The same happens in a vertical plane.

The next table shows a summary of this and other movements. If forces registered here repeat many times, they can produce enough stress to cause injuries. From this, we can conclude that it is very important to have control over this data.

Table 2

	Maximum V1 vertical (bw)		Maximum V2 vertical (bw)		V impulse (N · s)[a]	
Activity	*M*	*SD*	*M*	*SD*	*M*	*SD*
Running (3.8 m/s)	1.9	0.35	2.5	0.24	107.0	34.22
Cutting	3.0	0.54	2.3	0.25	132.9	47.21
Layup takeoff	2.7	0.57	3.2	0.35	273.0	59.62
Layup landing[b]	8.9	2.76	2.8	0.51	295.3	126.01
Jump shot takeoff	3.0	0.80	—	—	151.2	131.14
Jump shot landing[b]	6.0	1.43	2.0	0.76	210.6	132.31
Vertical jump takeoff	1.7	0.52	—	—	–89.3	103.50
Vertical jump landing[b]	4.3	1.16	1.3	0.40	–27.8	121.80
Shuffling	2.6	0.49	1.8	0.31	103.1	67.61

Source: McClay et al., 1994, p. 226.

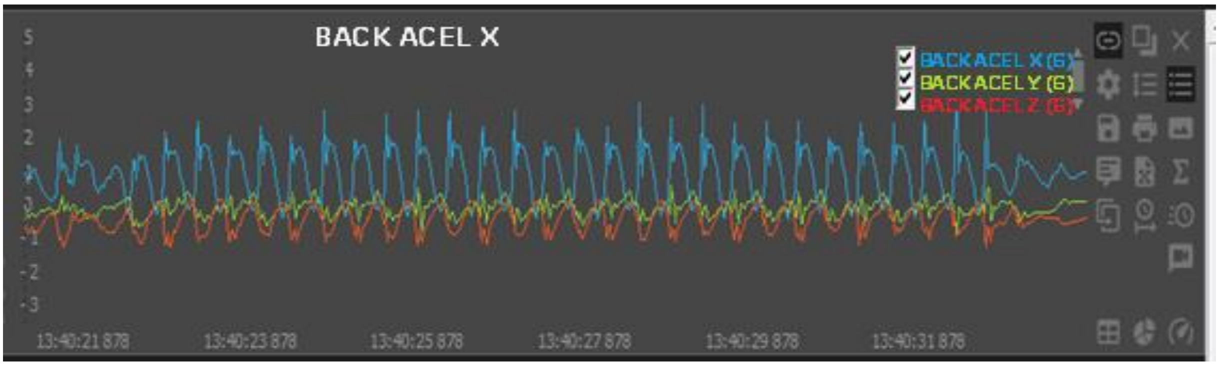
Table 3

Activity	Peak V		Peak AP		Peak ML	
	M	Range	*M*	Range	*M*	Range
Layup landing[a]	8.9	3.16 – 14.58	–2.5	1.4 – –6.60	–0.7	1.05 – –1.63
Jump shot landing[a]	6.0	3.12 – 9.76	1.1	–2.41 – 2.18	–0.3	0.28 – –0.56
Vertical jump landing[a]	4.3	3.16 – 7.84	1.1	–1.20 – 1.74	–0.4	0.26 – –0.93
Running	2.5	2.09 – 3.18	–0.4	0.52 – –0.61	–0.2	0.33 – –0.46

Source: McClay et al., 1994, p. 229.

Nowadays, for example, we can analyze this impact on a sprint, whereas, in the past, they could only measure it by using a force platform. We can know the impact in each of the steps players take in their movements.

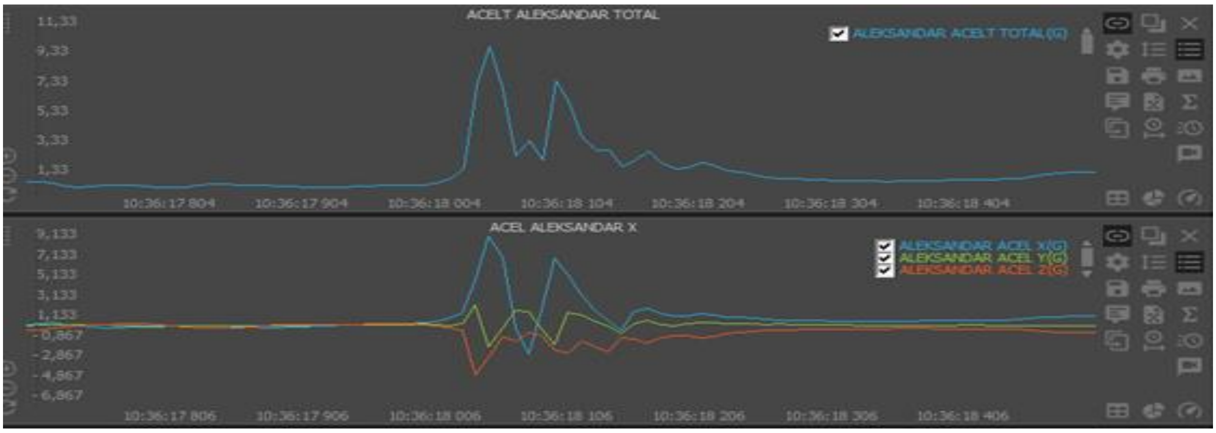
Figure 3



Source: Own creation based in: Realtrack Systems SL (2019).

We can also know the impact that a jump presupposes, whether after a layup or a jump shot.

Figure 4



Source: Own creation based in: Realtrack Systems SL (2019).

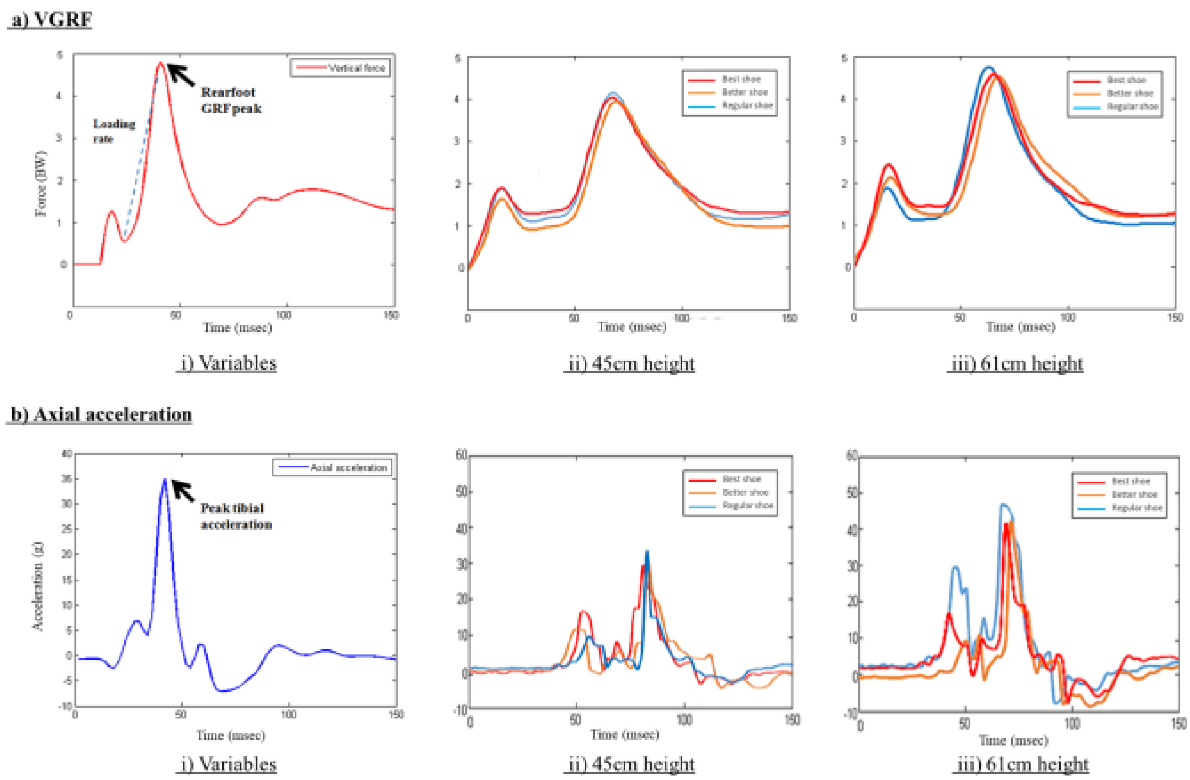
In 1687, Isaac Newton described his well-known laws. The first one was Newton's law of inertia: every object will remain at rest or will continue to move at a constant velocity, unless acted upon by a force. The second law confirms that the force of an object is equal to the mass of that object multiplied by its acceleration. In the third law, Newton talks about action-reaction forces: when one body exerts a force on a second body, the second body simultaneously exerts a force equal in magnitude and opposite in direction on the first body.

On the other hand, there is the law of gravity. Gravitational force or G force is based on the acceleration that Earth's gravity produced in an object. A G is equal to 9.8 m/s^2. This can be detected by an accelerometer. This way, basing on the acceleration produced by Earth's gravity in an object, we can measure the G force that players generate during their movements.

What do scientific publications say about using these devices in basketball?

In the article titled *Kinetics and perception of basketball landing in various heights and footwear cushioning* (2018), Wei, Wang, Woo, Liebenberg, Park, Ryu and Lam picked three different sport shoes in order to carry out observations. In figure 5, acronym VGRF stands for Vertical Ground Reaction Force.

Figure 5



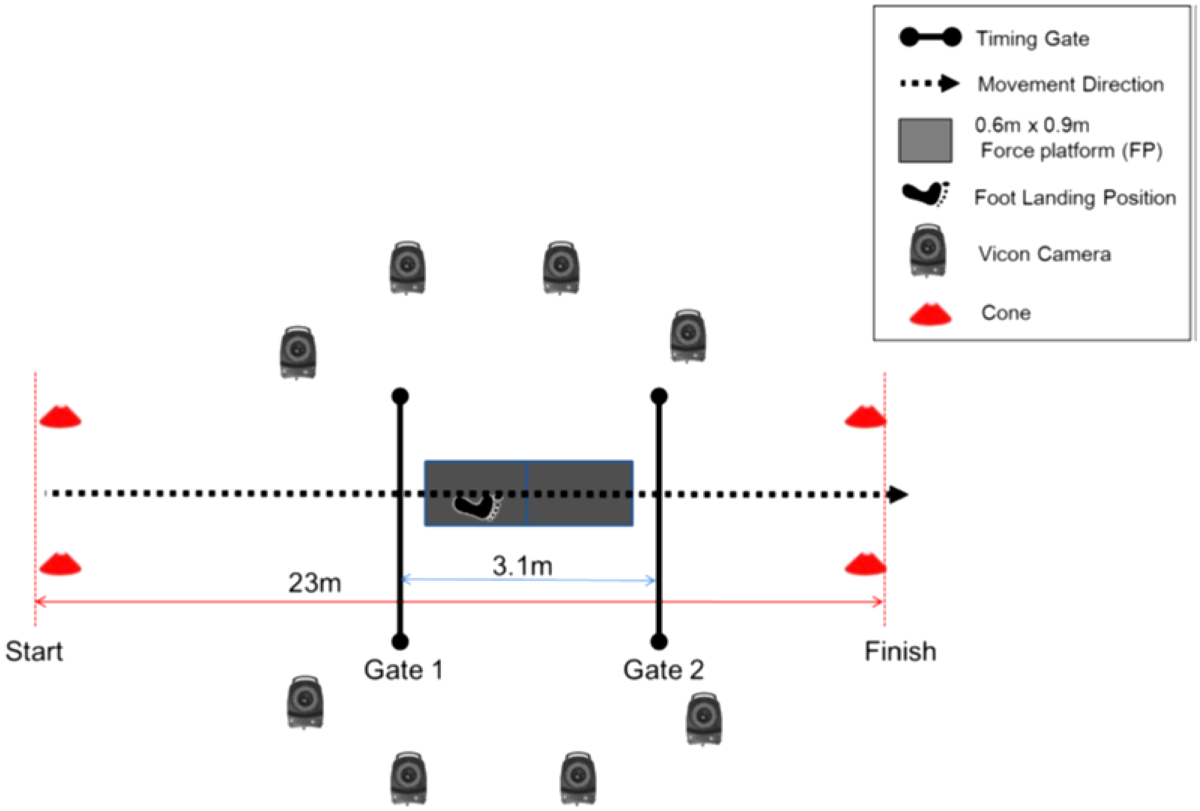
Source: Wei et al, 2018, p. 5.

Later, nineteen college basketball players were observed while doing a drop jump. It must be taken into account that data was obtained from the application of both systems: the usage of a force platform and the application of an accelerometer to measure tibial acceleration.

From these measurements, it was observed that shoes had an optimal damping system, in order to improve protection against tibial stress fracture. It is important to highlight that the cited research was the result of the search for solutions to these types of injuries.

Furthermore, comfort perception correlated with load or impact. This implies that they can set a degree of subjective perception to estimate the level of impact load in situations outside laboratories.

Figure 6

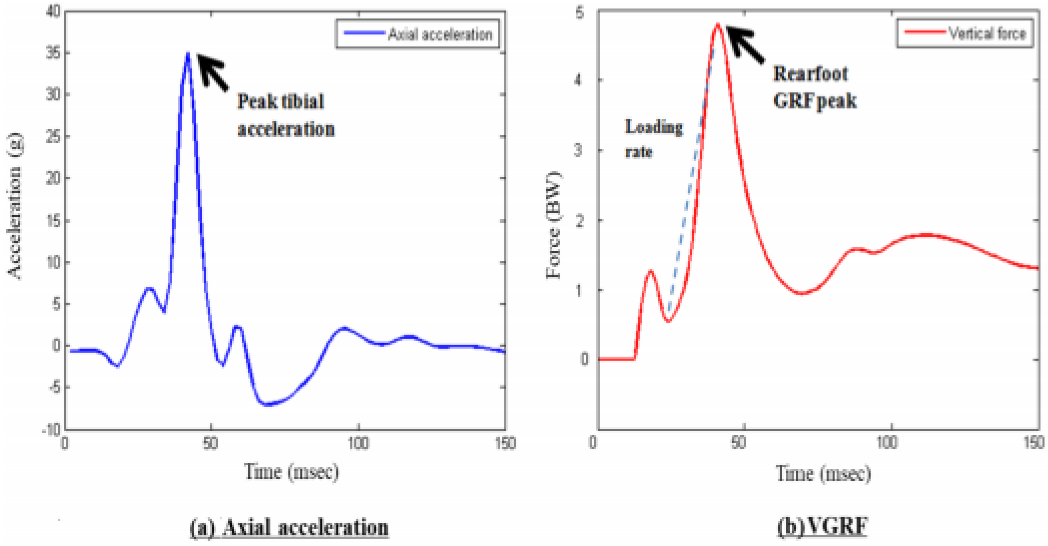


Source: Lam, Liebenberg, Woo, Park, Yoon, Tsz-Hei Cheung and Ryu, 2018, p. 4.

In Lam, Liebenberg, Woo, Park, Yoon, Tsz-Hei Cheung and Ryu (2018) study, they measured the forward sprint in eighteen basketball players in two different intensities, three meters per second and six meters per second.

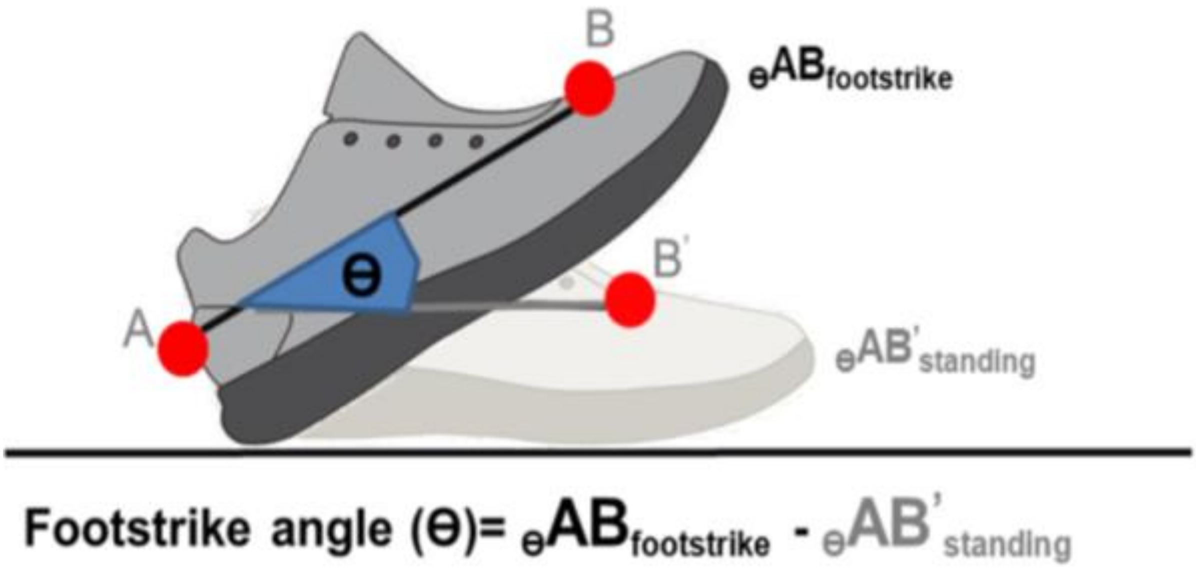
All this data was recorded with cameras that allowed comparing information obtained in the force platform and in the accelerometer.

Figure 7



Source: Lam et al., 2018, p. 5.

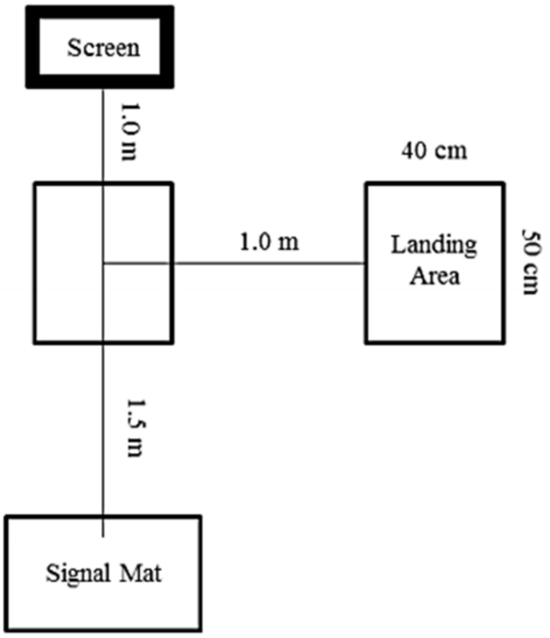
Figure 8



Source: Lam et al., 2018, p. 4.

Players had to make different movements in response to unexpected actions from team partners and opponents. This data is related to the ball and the basket. It must be taken into account that it is about a limitation for their ability to anticipate the movement.

Figure 9

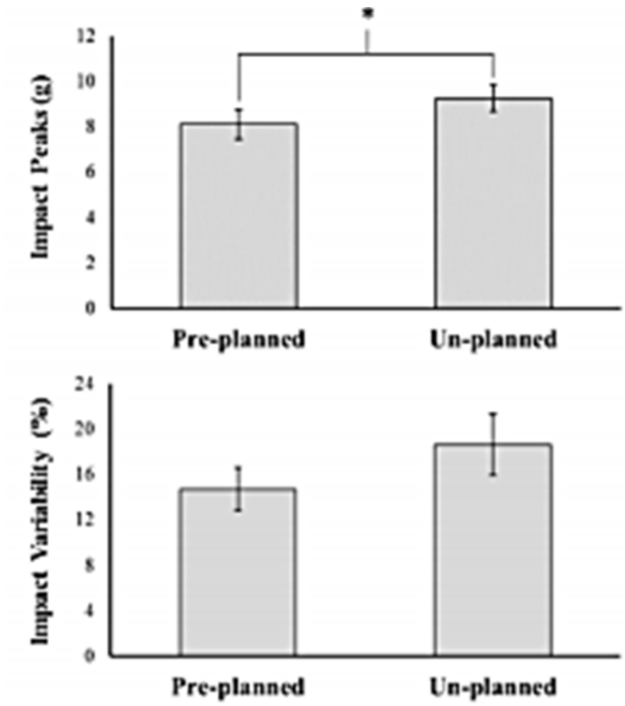


Source: Lucas, England, Mason, Lanning, Miller, Morgan and Thomas, 2018, https://n9.cl/kfxb.

The purpose of the study was to compare accelerations during a pre-planned or un-planned change of direction.

The conclusion was that the impact was bigger in unexpected actions. This means that the mechanical stress players supported in an unexpected action was bigger and, besides, that the impact variability was also bigger than in the un-planned actions.

Figure 10



Source: Lucas et al., 2018, https://n9.cl/kfxb.

Another study in which WIMUs have been used is the one from Beato, De Keijzer, Carty and Connor titled *Monitoring Fatigue During Intermittent Exercise With Accelerometer-Derived Metrics* (2019). This study's main goal was to evaluate sensitivity of data derived from WIMU for monitoring fatigue during an intermittent exercise protocol. They used different variables, from which we are going to highlight the dynamic stress load (variable that is related to the mechanical load that players suffer in each impact they do) and the fatigue index (dynamic stress load normalized for each meter that was covered). Looking at the results, we conclude that the dynamic stress load, as well as the fatigue index can be parameters that will allow us to quickly monitor fatigue that players can experience when doing a resistance intermittent exercise.

Table 4

Variables	Drill 1 (SD)	Drill 2 (SD)
DSL (AU)	35.1 ± 12.7	38.1 ± 11.0
DSL·m^{-1} (AU)	0.038 ± 0.014	0.041 ± 0.012
FI (AU)	0.71 ± 0.25	0.76 ± 0.22

Source: Beato et al., 2019, https://n9.cl/v6m6.

This proposal can be applied in basketball.

For example, we could propose a test to detect fatigue. This will allow us to anticipate and make decisions when periodizing or individualizing work done by each one of our players, in relation to data obtained with the dynamic stress load or the fatigue index.

Another important publication is the project by Scanlan, Fox, Milanović, Stojanović, Stanton and Dalbo (2019). In that study player load was used. This variable represents basically the square root of the sum of the difference in instantaneous accelerations in each of the axes to the square.

Figure 11

$$\text{Player load} = \sqrt{\frac{(a_{y1} - a_{y-1})^2 + (a_{x1} - a_{x-1})^2 + (a_{z1} - a_{z-1})^2}{100}}$$

Source: own creation.

These authors' project is to use the player load by individualized or fixed thresholds. This way, they established that loads in arbitrary units obtained through WIMU in fixed thresholds were from zero to one. Zone 1 from one to two, zone 2 from two to three, zone

3 from three to four, zone 4 from four to five, zones 5 and 6 from four to six. Zone 5 and zone 6 established from six to ten arbitrary units. In relation to individual thresholds that were fixed in zone 1, they corresponded between zero and ten percent. Zone 2, between ten and twenty percent. Zone 3, between twenty and thirty percent. Zone 4, between thirty and forty percent. Zone 5, between forty and sixty percent. And zone 6, between sixty and a hundred percent. In the next figure, differences between both methods can be seen.

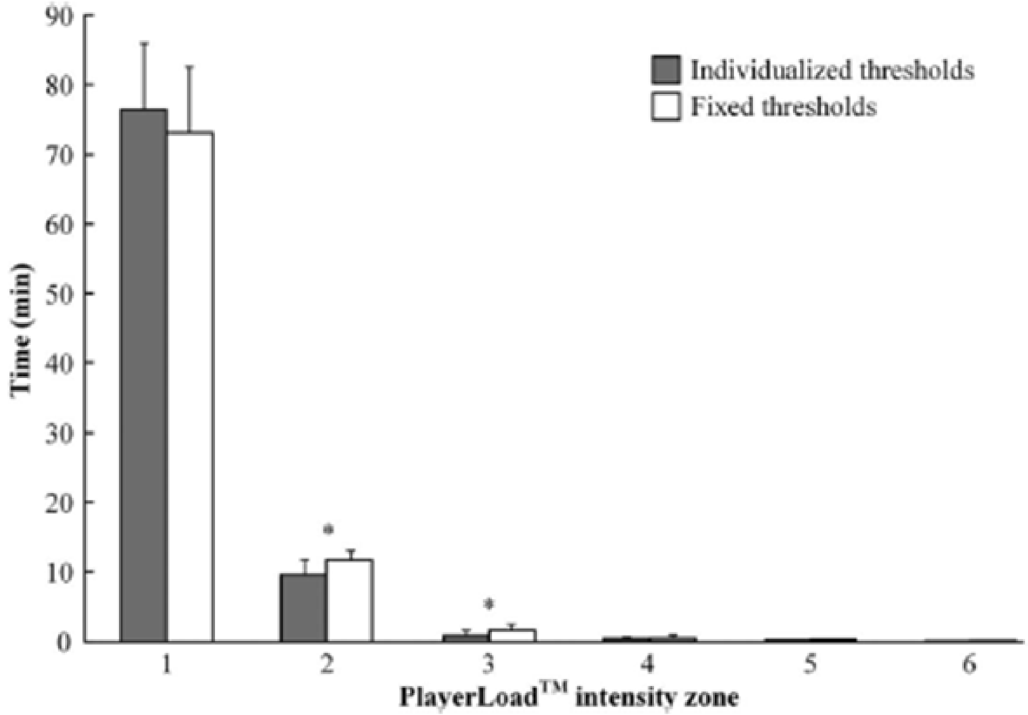
Figure 12

Zone	Individualized (% of peak PlayerLoad)	Fixed (absolute PlayerLoad)
1	0–10%	0–1 AU
2	10–20%	1–2 AU
3	20–30%	2–3 AU
4	30–40%	3–4 AU
5	40–60%	4–6 AU
6	60–100%	6–10 AU

Source: Scanlan et al., 2019, https://n9.cl/oye7z.

The fixed approach produced a longer training period in zones 2 and 3. The conclusion is that variations in results between both approaches must be considered when quantifying the time devoted to work in different zones.

Figure 13

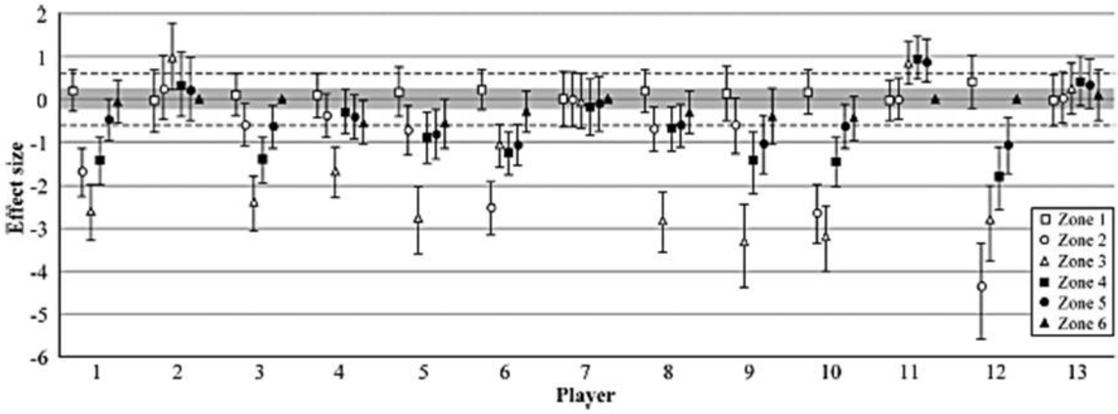


Source: Scanlan et al., 2019, https://n9.cl/oye7z.

Results show that we should not only establish measurements by taking measures in fixed zones, but we should also take individual thresholds into account, in relation to each player requirements. As we have already pointed out in other modules, it is necessary to highlight the need to individualize the load of each one of the players.

On the other hand, we should remember that the individualized player load is determined by the maximum peak obtained by each player. From there, the load percentage for each zone is calculated.

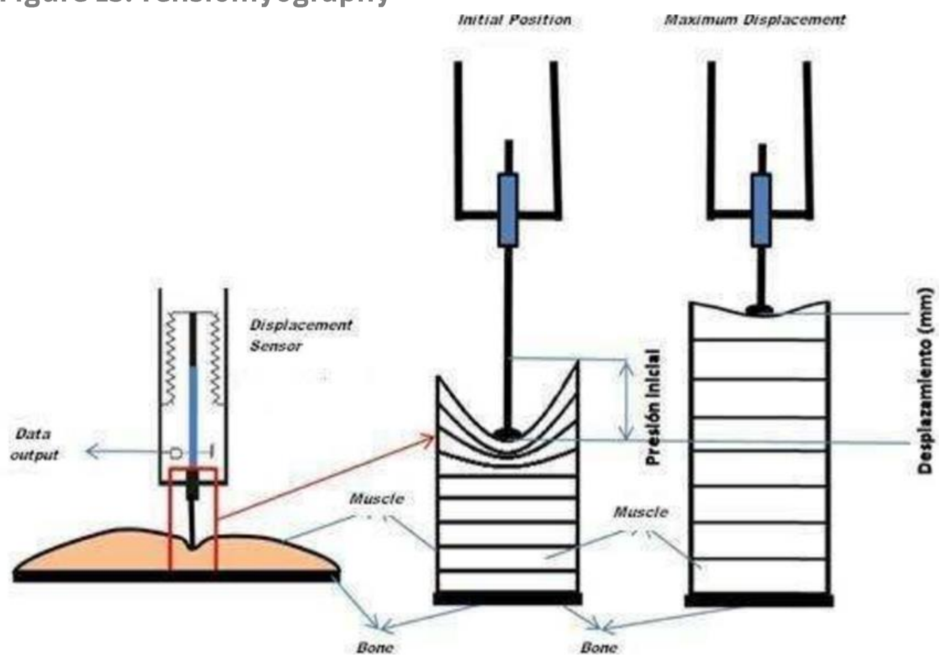
Figure 14: Player load differences among players in relation to time spent within each intensity zone



Source: Scanlan et al., 2019, https://n9.cl/oye7z.

Tensiomyography is a technique that allows for detecting and analyzing superficial muscles contractile properties separately. Below, we will see how from this technique, they establish a diagnosis method that works through observation of geometric changes that happen in abdomen when contracting the muscle.

Figure 15: Tensiomyography



Source: [Untitled image of tensiomyography]. (s.f.). Recovered from: https://n9.cl/e2x6.

Presión inicial	Initial pressure
Desplazamiento (mm)	Displacement (mm)

The device should be placed on the abdomen and it is given a "discharge". This will cause the device movement and, consequently, the abdomen movement. Tensiomyography allows monitoring the state of muscle fibers and its evaluation control, obtaining selective data from analyzed muscles.

Below, we will briefly describe different variable concepts that we have to know.

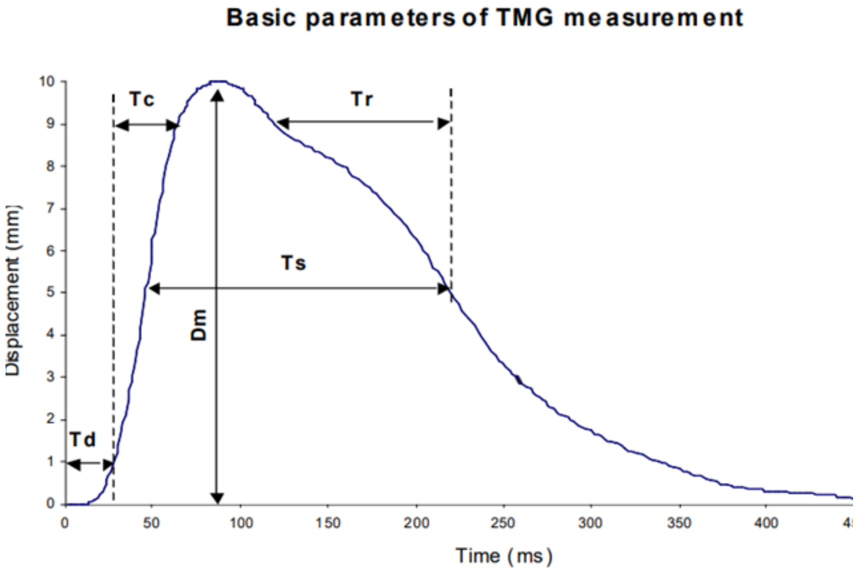
TD is the time delay and it measures the delay time the muscle needs to get to the 10% of the maximum movement done by the time contraction (TC).
TC is time contraction and it measures the time that the muscle needs to get to the 90% of the maximum movement generated.
TR is the relaxation time that provides information about the fatigue index.
TS is the time needed for stabilizing the muscle response facing the movement we have generated.

Another variable is the same muscle movement that evaluates muscle rigidity.

We also have to take into account the abdomen length, which is affected by the muscle morphologic and functional characteristics and the type of training and/or treatment we might offer.

Low movement values show us a great amount of tone and an excessive rigidity of the muscle analyzed. High values indicate lack of muscle tone.

Figure 16: Basic parameters of TMG measurement



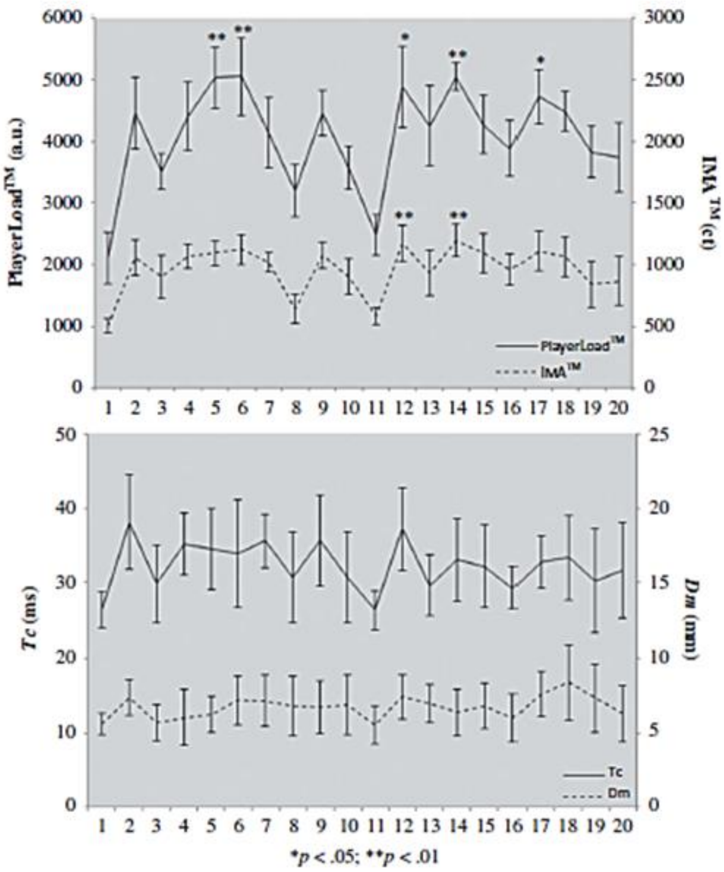
Source: Basic parameters of TMG measurement (s.f.). Recovered from: https://n9.cl/e2x6.

Below, we will analyze Kyle Peterson and Gabriela Quiggle (2016) study titled *Tensiomyographical responses to accelerometer loads in female collegiate basketball players*. In this study, they measured accelerations and decelerations in different training sessions. Also they used tensiomyography for the analysis of femoral rectum muscle, femoral bicep muscle and the long adductor muscle. Absolute values obtained were analyzed, but also the change percentages that were established in time. The main discoveries showed that the relative change lower than 10% corresponded to the best players' adaptation to supported training loads. Therefore, the two pieces of information the study provided measured aspects of the external load or physical demands and of internal load (neuromuscular) through tensiomyography.

The second important discovery was that data measured by WIMU (accelerations and decelerations), especially in the squad on the laterals, was useful to establish the best adaptations in players. The long adductor muscle was the one that best allowed adaptations.

Finally, it was established that it was better to use the change of values percentage obtained in relation to the absolute value. That is to say, the change percentages allowed a better comprehension of absolute values obtained.

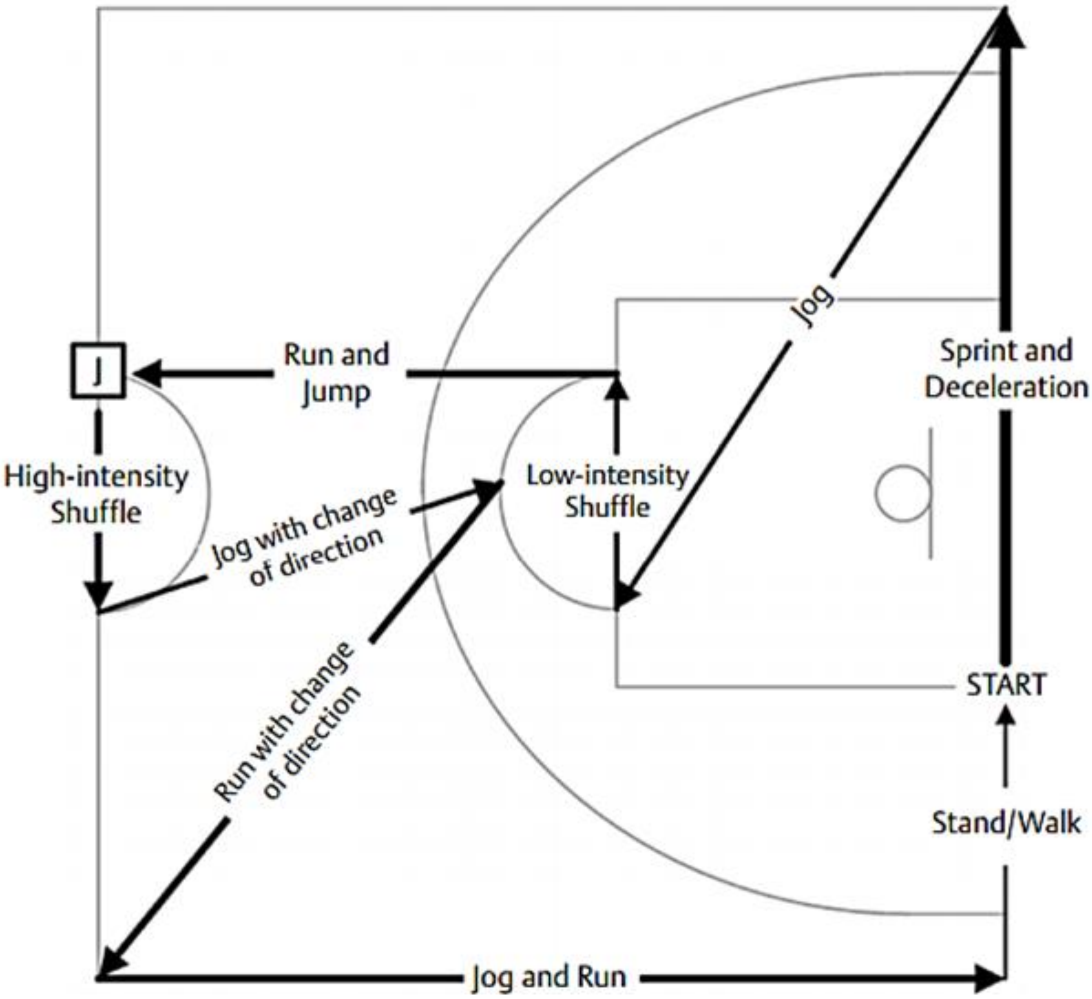
Figure 17



Source: Peterson and Quiggle, 2016, p. 4.

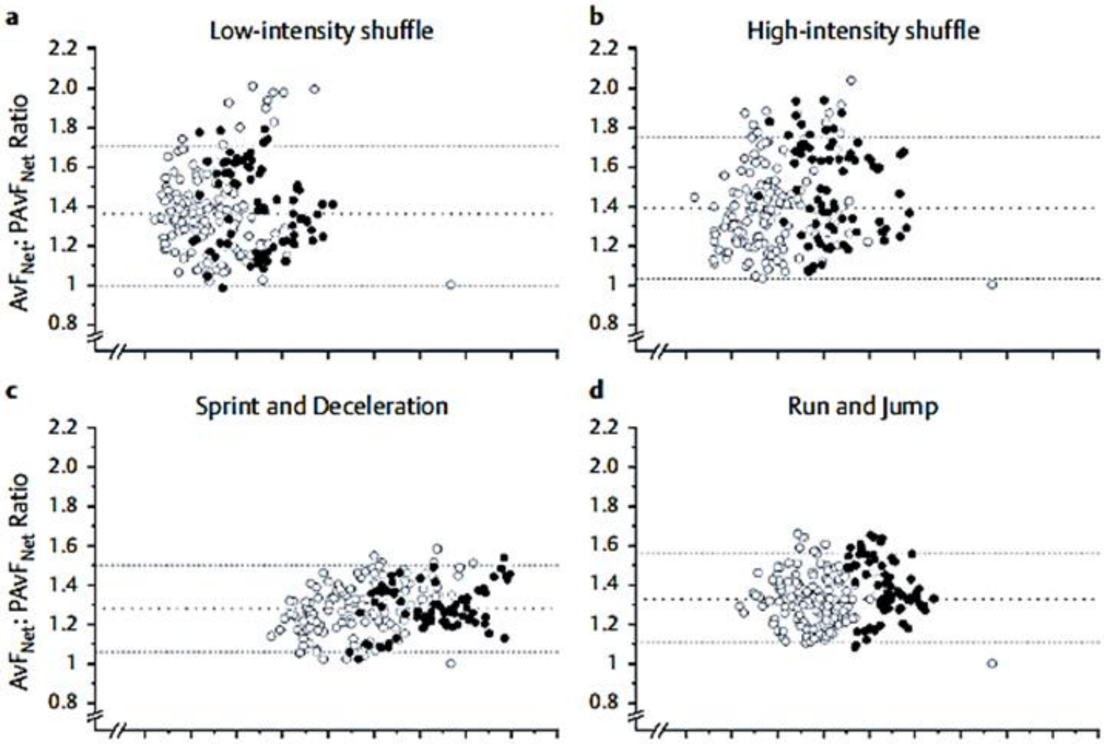
Another interesting publication is the Staunton, Wundersitz, Gordon and Kingsley (2017) study titled *Construct Validity of Accelerometry-Derived Force to Quantify Basketball Movement Patterns.* The study consisted in doing a yo-yo test and then a BEST (basketball exercise simulation test) test. The BEST is a circuit with different movement patterns in which athletes execute sprints, decelerations, side shuffles and changes of direction on one half of the basketball court. The goal was to validate the WIMU systems.

Figure 18



Source: Staunton et al., 2017, https://n9.cl/pxrcz.

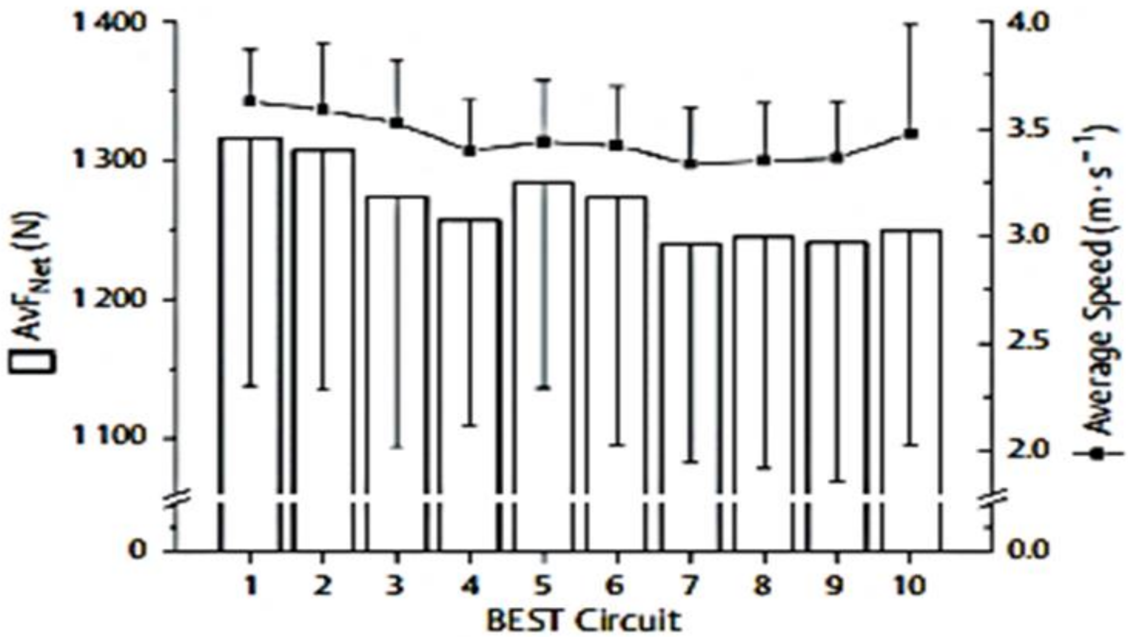
Figure 19



Source: Staunton et al., 2017, https://n9.cl/pxrcz.

Using accelerometry they could obtain the force measure produced in each of the impacts. As a conclusion, it is highlighted that WIMUs were a valid means to detect physical demands that the player supported in the movement patterns that were included in the test.

Figure 20

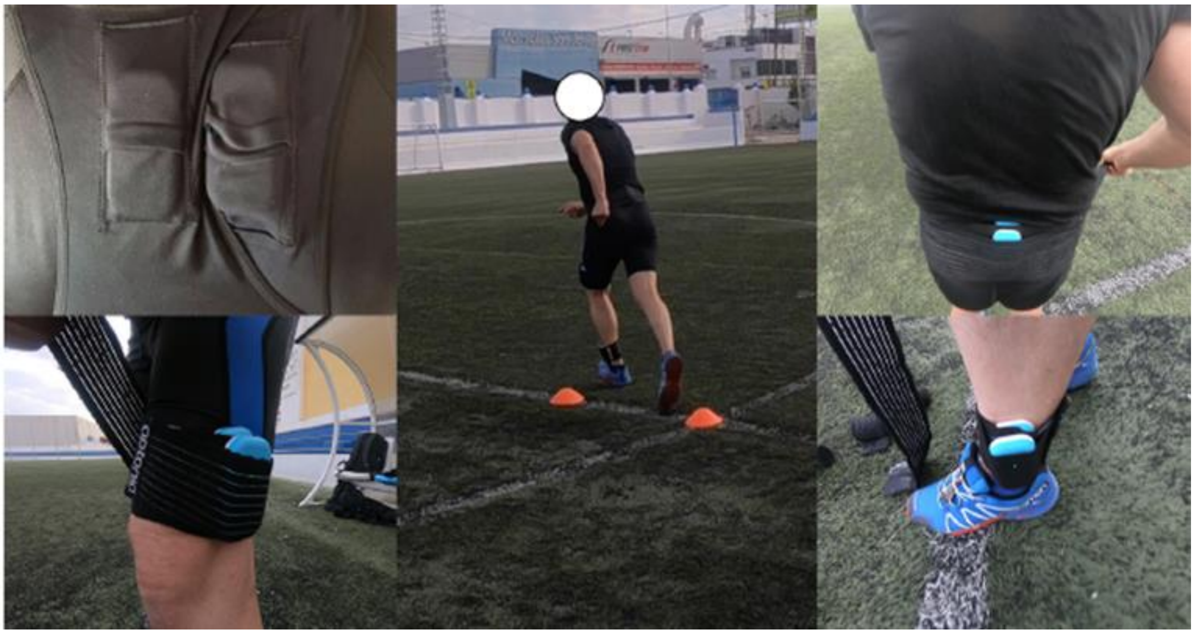


Source: Staunton et al., 2017, https://n9.cl/pxrcz.

In this sense, it is very important to know about the validity and reliability of technology used.

Gómez-Carmona, Bastida-Castillo, García-Rubio, Ibañez and Pino-Ortega (2018) publication analyzed WIMU's reliability in basketball and football. The study evaluated reliability in accelerometers that contain inertial devices to measure physical demands.

Figure 21



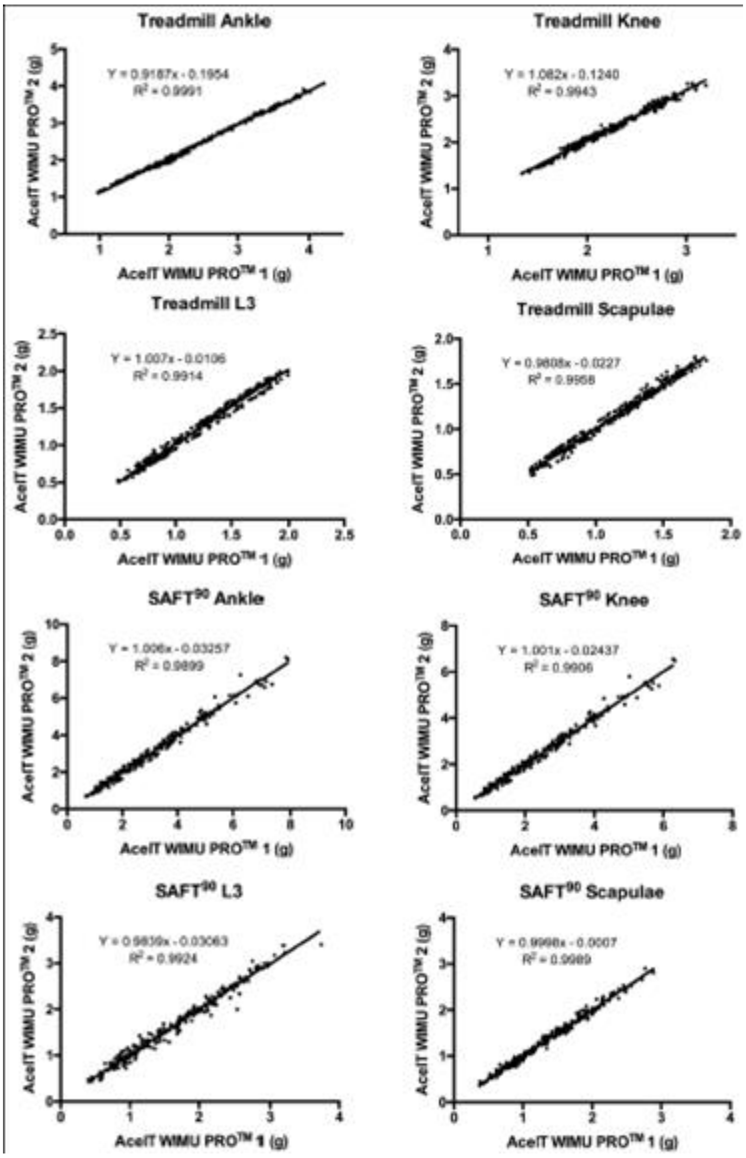
Source: Gómez-Carmona et al., 2018, https://n9.cl/g1rr.

They put four devices for the laboratory and another eight to measure different tests that are more specific to the sport activity in laboratory. Static and dynamic situations were applied, using 10 and 30 hertz vibration.

For specific tests, they used an incremental progressive test on a treadmill and a SAFT90 test for movements. In order to calculate total acceleration, they put devices on ankles, knees, lower back and in the scapulae zone. This way, results showed an excellent static reliability inside and among devices. And a very high reliability in the incremental test on the treadmill and also in the SAFT90 test.

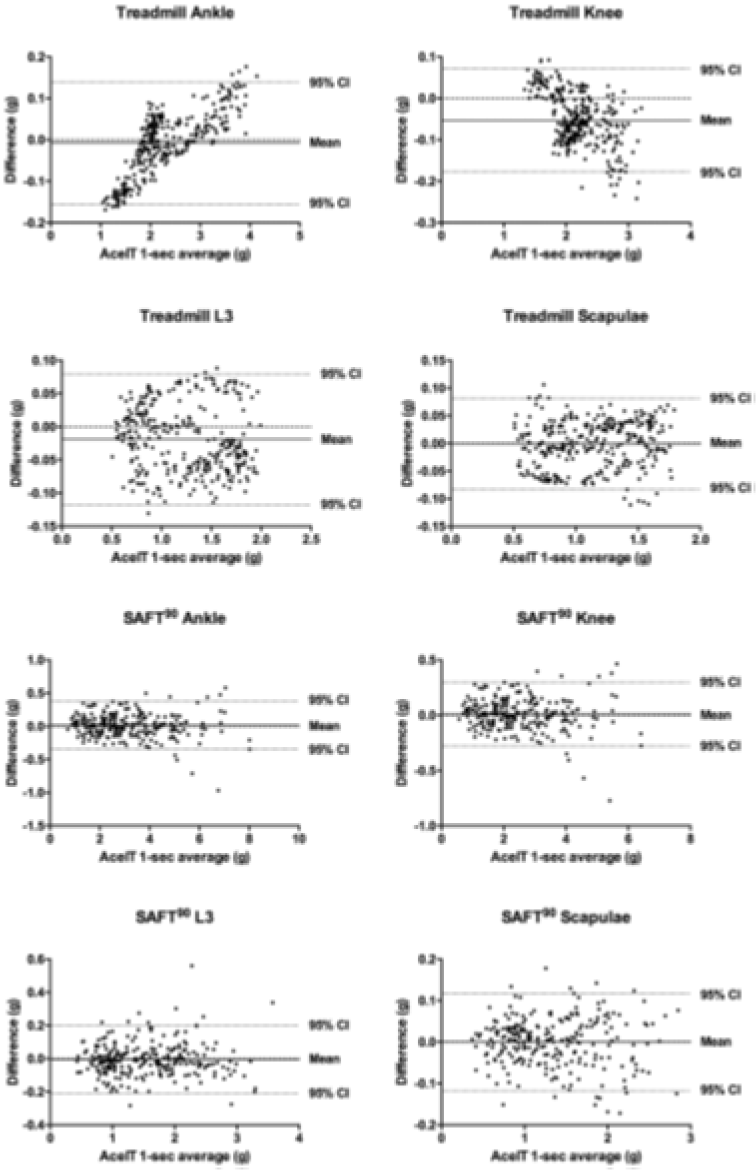
These devices are reliable in the typical basketball or football actions because they have similar movement patterns.

Figure 22



Source: Gómez-Carmona et al., 2018, https://n9.cl/g1rr.

Figure 23



Source: Gómez-Carmona et al., 2018, https://n9.cl/g1rr.

Why can physical demands be measured by WIMUs in basketball?

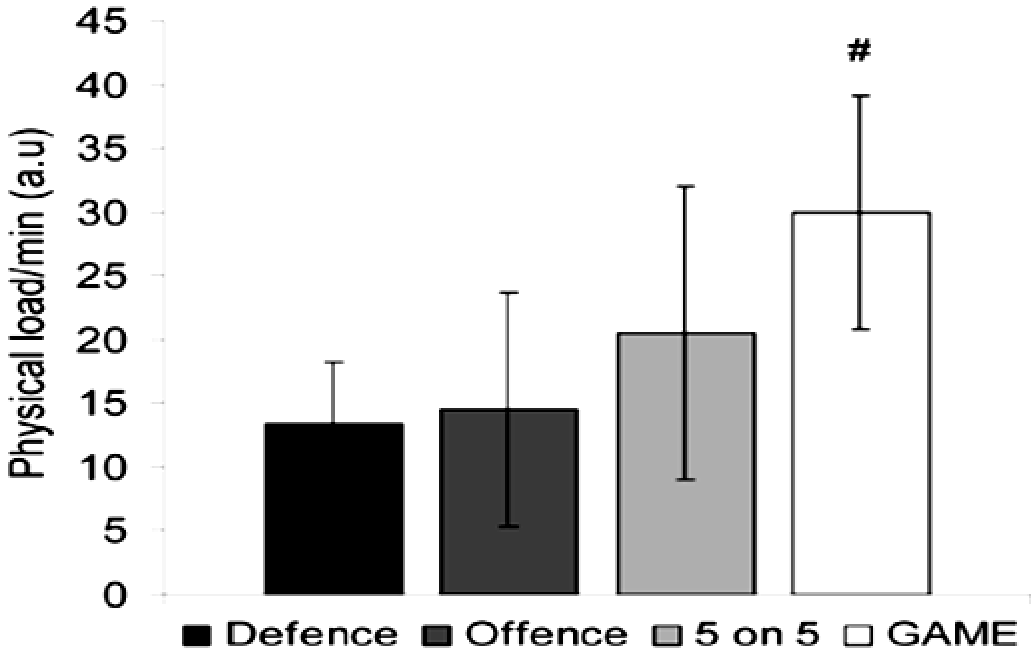
Because typical basketball actions include global whole body movements that could be measured by accelerometers. This way, we can detect all the impacts, whether in running, in changing directions or in jumping.

Montgomery, Pyne and Minahan (2010) publication's goal was to characterize physical and physiological responses during different exercises done by eleven junior elite basketball players.

On the one hand, measurements were taken during three competition matches. On the other, during two training weeks, they monitored defense, offense and five on five exercises on one half of the court. The total number of exercises measured was of 190 in defense, 57 in offense and 48 in five on five on half of the court. Besides, they characterized the physical and physiological responses and they calculated the player load.

By calculating the player load, they could obtain external load data in arbitrary units. This way, they could also compare each one of the exercises that were carried out, including competition.

Figure 24

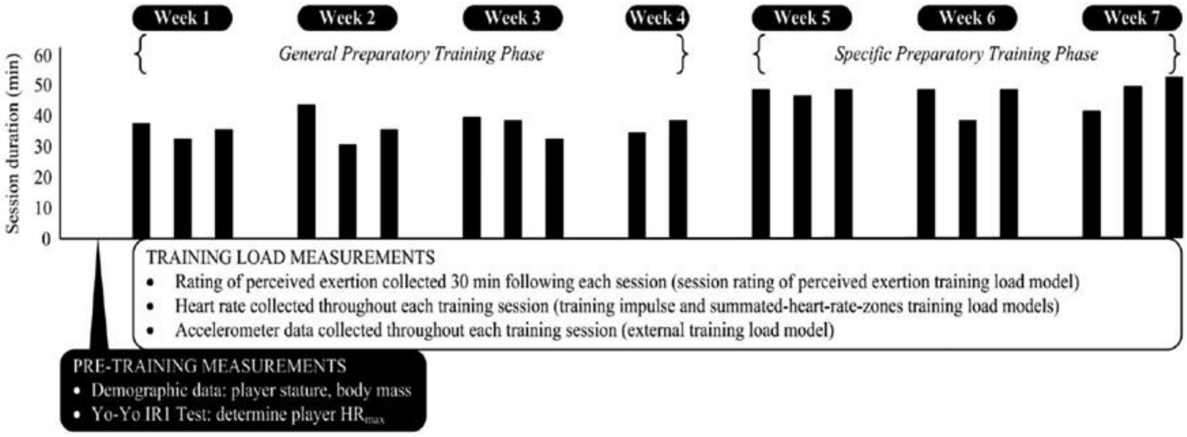


Source: Montgomery et al., 2010, p. 82.

As it is observed in the figure, proposed offense and defense exercises presented similar physical and physiological demands. While the five on five demands in training were significantly lower than the five on five in competition.

Scanlan, Wen, Tucker and Dalbo (2014) compared internal and external load in basketball. Eight semi-professional basketball players were part of this study. They analyzed forty four sessions in seven different weeks and they compared internal and external load.

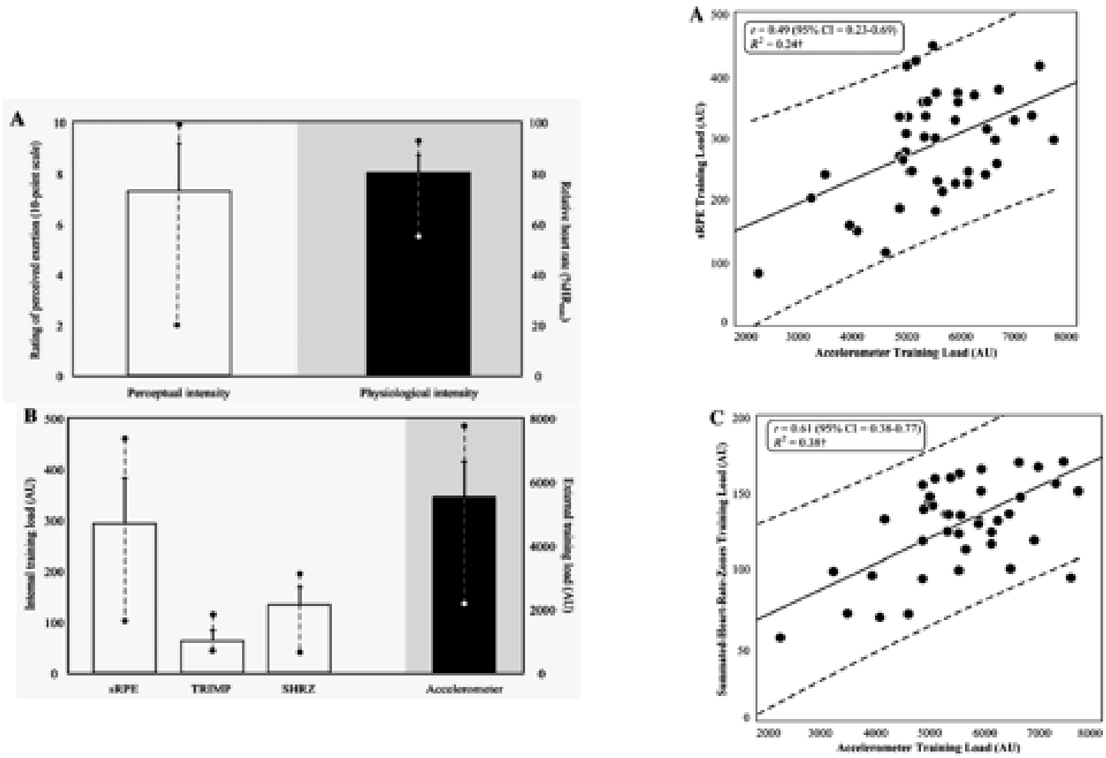
Figure 25



Source: Scanlan et al., 2014, https://n9.cl/0ms6.

External load was given by the player load, while the internal load demands were established through the heart rate.

Figure 26



Source: Scanlan et al., 2014, https://n9.cl/0ms6.

Results showed that there is no a linear response between the external and internal load, e.g. the body movements and the internal response are two different constructs. Therefore, it is necessary to consider both approaches in order to optimize the training process in basketball.

In order to get this data, they established that the correlation between internal and external load was not high. Therefore, we can conclude that if we want to rigorously optimize sport performance, it is necessary to deal with both approaches simultaneously.

Another important publication is the one by Fox, Stanton and Scanlan (2018), titled *A Comparison of Training and Competition Demands in Semiprofessional Male Basketball Players*. In this case, the base of their goal was to quantify and compare the required physical demands in basketball training sessions as well as in matches. Fifteen semi-professional players were part of this. They distinguished three training stages: one for fitness adaptation, one for specific court training and another one that included matches. They used variables like player load and RPE session. In relation to the internal load variable, they used the heart rate by intensity zones and, in relation to physical demands variable, they also did an estimation of distance through accelerometer and gyroscope acceleration data.

In the first stage, they obtained a player load of 6.5 arbitrary units per minute. In the specific physical part, they got 6.1 units per minute. In the competition part, they got 4.35 units per minute.

In the general physical, the estimated distance was of 61.88 meters per minute. In the specific physical was of 56.76 meters per minute. In competition was of 41 meters per minute.

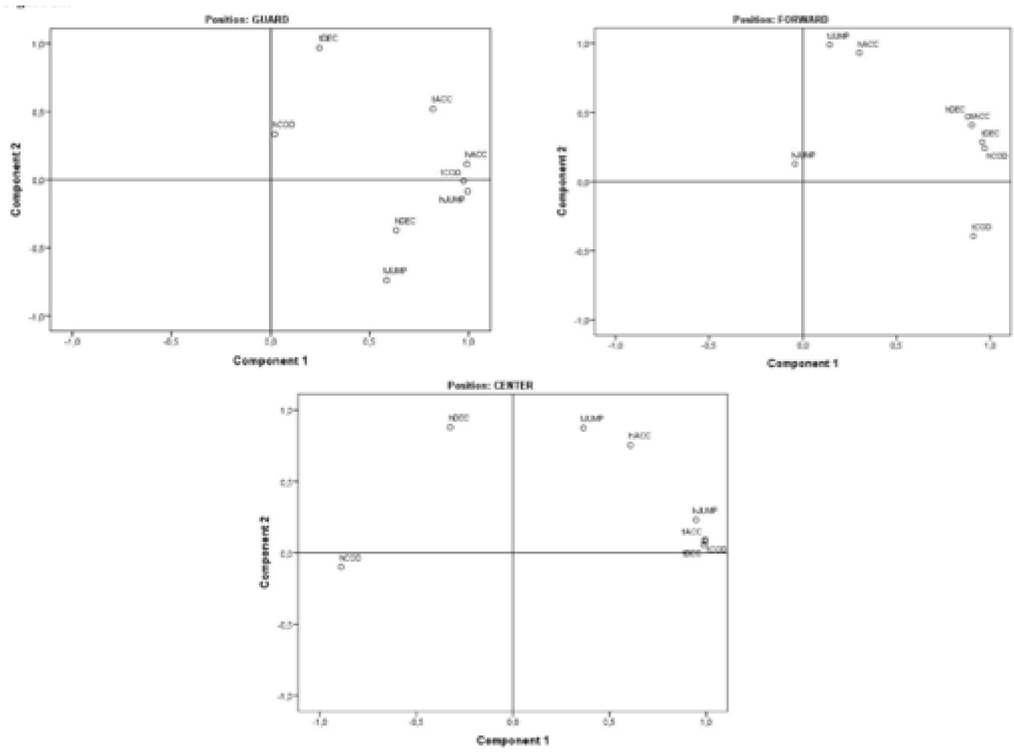
In this study, physical demands required for matches were lesser than in training sessions. Therefore, the conclusion is that training demands were bigger than match physical demands.

For their part, in their article, Svilar, Castellano, Jukic and Casamichana (2018) included thirteen professional players in the three game positions. The main goal was to compare training physical demands in the different positions in elite basketball.

In the study, they analyzed different variables: total acceleration, high intensity acceleration, total high intensity deceleration, total high intensity changes of direction, total jumps, high intensity jumps and RPE. The statistical analysis of main components showed two and three main components, but each factor configuration was different according to the game position of each of the players. RPE and session RPE in all positions also showed a high correlation with the total amount of accelerations, decelerations and changes of direction. This suggested that, although players did the same training tasks, physical demands by position were different for each of them.

This way, Svilar et al. publication (2018) establishes different quadrants through the analysis of the main components that show guards, forwards and centers requirements.

Figure 27



Source: Svilar et al., 2018, https://n9.cl/e8utr.

In conclusion, each game position is associated with a concrete combination of physical demands. This allows for a better understanding of internal responses among players.

Next figure belonging to a Vázquez-Guerrero, Suarez-Arrones, Casamichana Gómez and Rodas (2018) article shows data about our team in two official matches measured by WIMU.

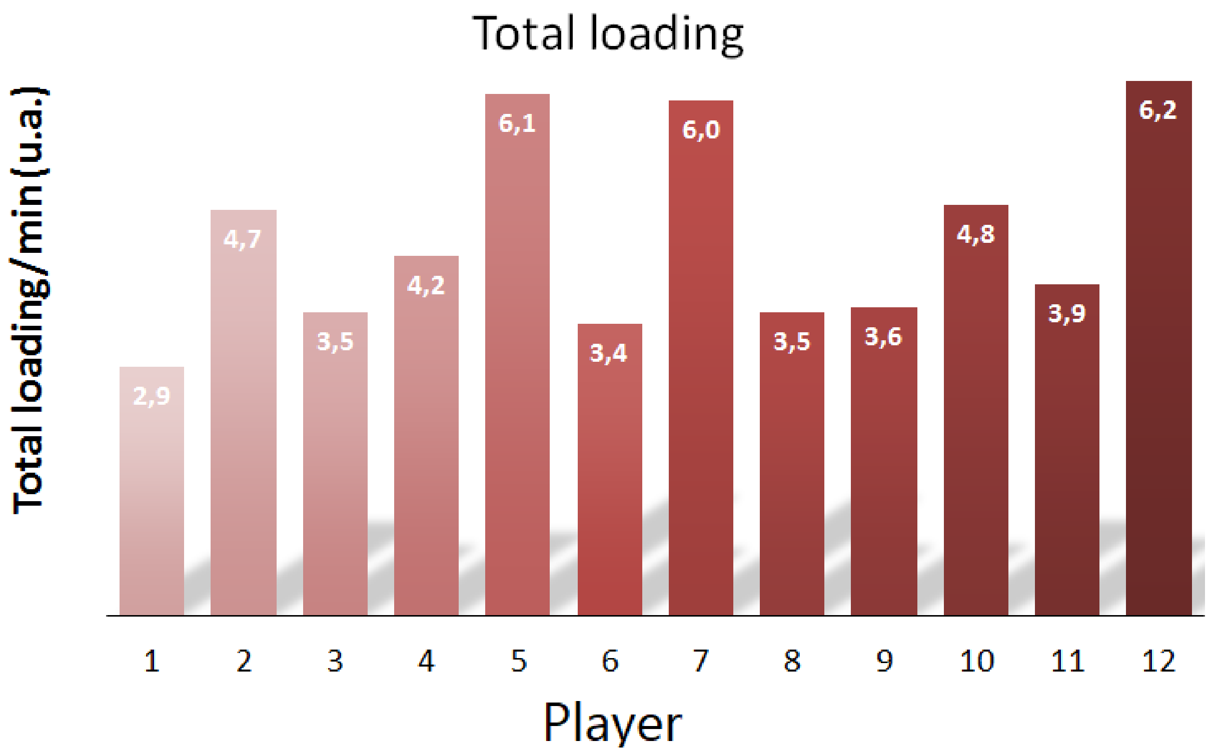
Figure 28

Variables	Playing positions				
	Point guards (*n*=4)	Shooting guards (*n*=6)	Small forwards (*n*=4)	Power forwards (*n*=4)	Centers (*n*=5)
# Accelerations (<3 m·s^{-2}) #/min	*29.6±3.9	*32.7±11.0	*26.7±2.6^{a,b,e}	*28.0±5.0	*28.3±1.1
# Accelerations (>3 m·s^{-2}) #/min	1.4±0.9	1.0±0.4^{d,e}	0.8±0.3^{a,d,e}	1.4±0.5	1.5±0.4
# Decelerations (<3 m·s^{-2}) #/min	23.8±3.6	25.7±10.0	21.7±2.2^{e}	24.0±4.6	23.4±1.3
# Decelerations (>3 m·s^{-2}) #/min	*4.5±1.4	*4.1±0.5	*3.2±0.7^{a,b}	*3.5±0.7^{a,b}	*3.7±0.8^{a}
Acc : Dec Ratio (<3 m·s^{-2})	1 : 0.80±0.04^{d,e}	1 : 0.78±0.06^{c,d,e}	1 : 0.81±0.01^{d,e}	1 : 0.86±0.02	1 : 0.83±0.02^{d}
Acc : Dec Ratio (>3 m·s^{-2})	1 : 3.94±1.3	1 : 4.87±1.8	1 : 4.26±0.8	1 : 2.67±0.4^{a,b,c}	1 : 2.57±0.5^{a,b,c}
External total load (AU/min)	4.8±1.1	4.6±1.7	4.8±0.8	3.5±1.1^{a,b,c,e}	4.4±0.3

Source: Vázquez-Guerrero et al., 2018, p. 231.

Later, they established the ratio between accelerations and decelerations.

Figure 29

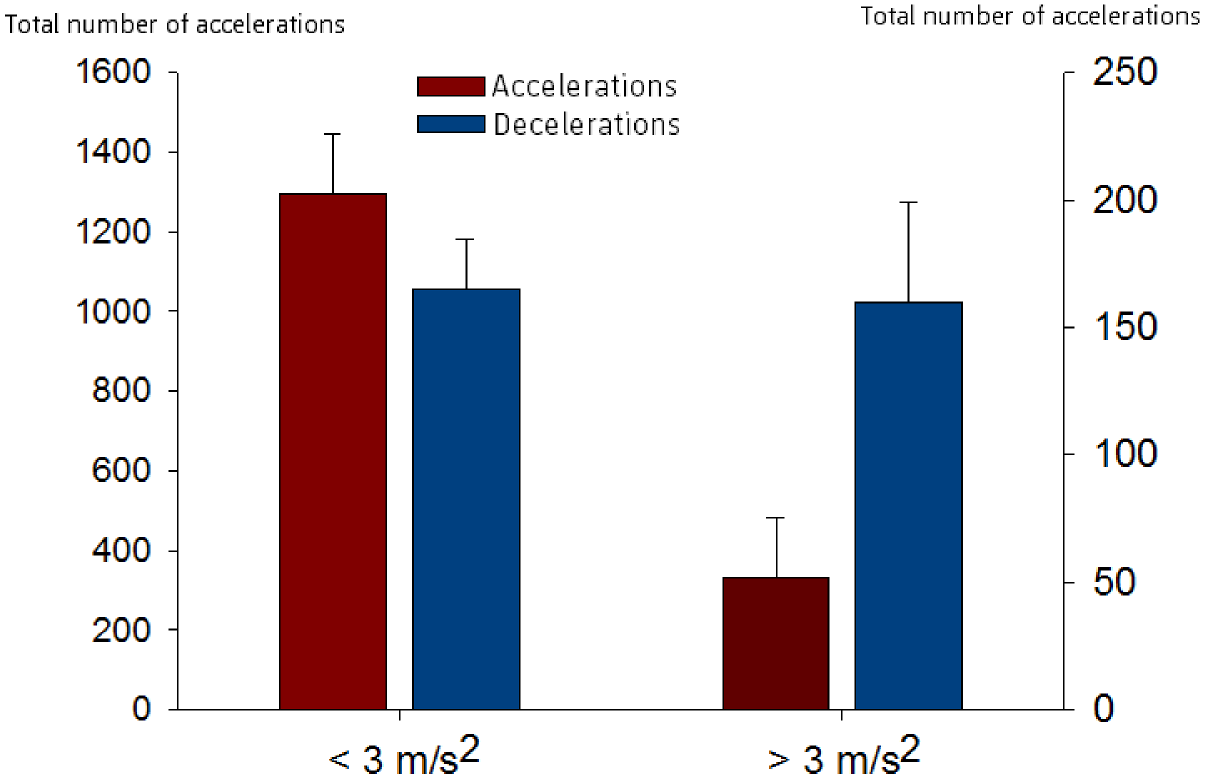


Source: Vázquez-Guerrero et al., 2018.

The first piece of information that can be appreciated is the player load (total loading in the previous figure). We can see that requirements for each player and each position are different.

The most interesting thing about this study is that they also quantified the number of accelerations and decelerations required in the match.

Figure 30

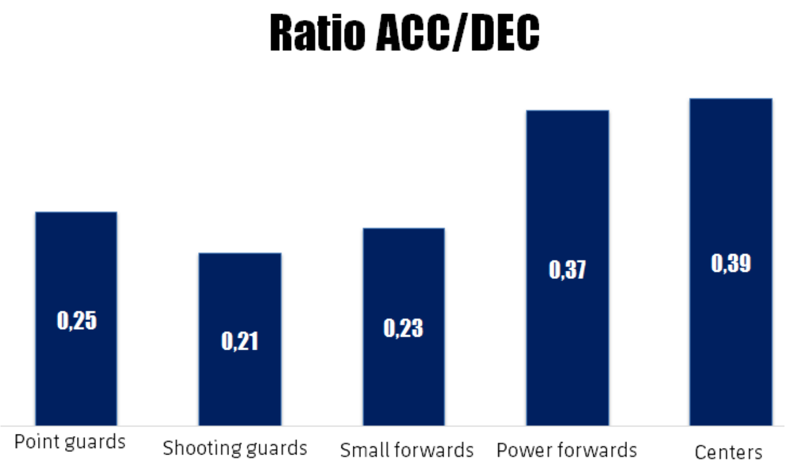


Source: Vázquez-Guerrero et al., 2018.

Another very interesting thing is that they established the acceleration and deceleration ratio (including the vertical axis) not only for a zone smaller than three meters per second squared, but also for a zone bigger than three meters per second squared. What we see is that in the zone bigger than three meters per second squared, the number of high intensity accelerations is smaller than the number of high intensity decelerations (previous figure). This gives us very relevant information in order to periodize our training and, mainly, to train our players in pre-season, so that they can support match physical requirements and demands more effectively.

Another interesting piece of information in this study is that the acceleration/deceleration ratio is lower outside.

Figure 31



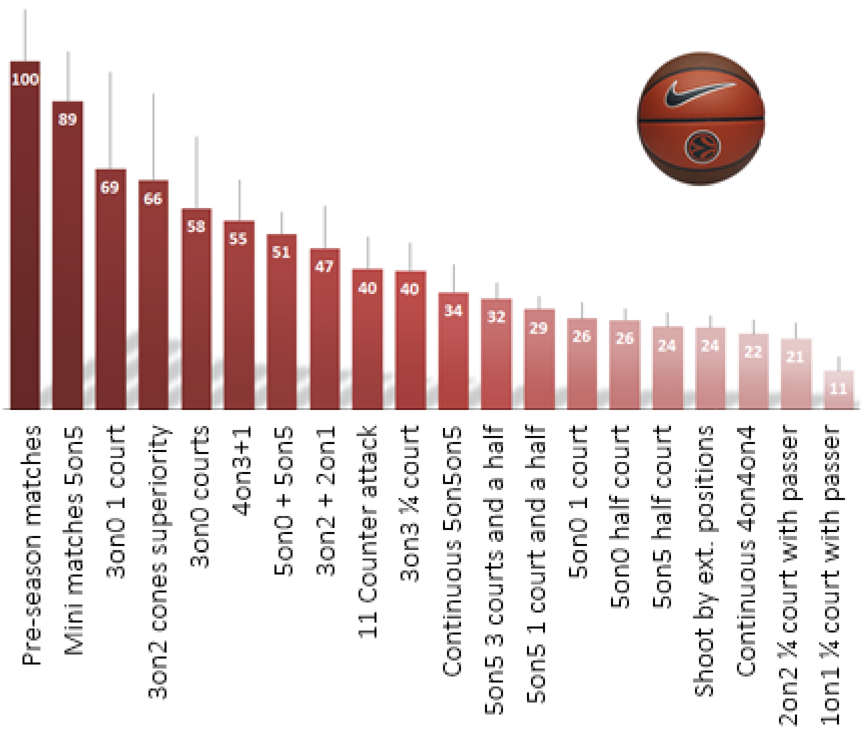
Source: Vázquez-Guerrero et al., 2018.

High intensity accelerations were smaller in relation to high intensity decelerations. When that ratio was analyzed, perimeter players showed even more demands for high intensity jump stops in relation to accelerations.

We should give a lot of importance to this information about the high intensity acceleration and deceleration ratio.

This data allowed us to set a group of exercises in relation to the maximum percentage, which was a hundred percent.

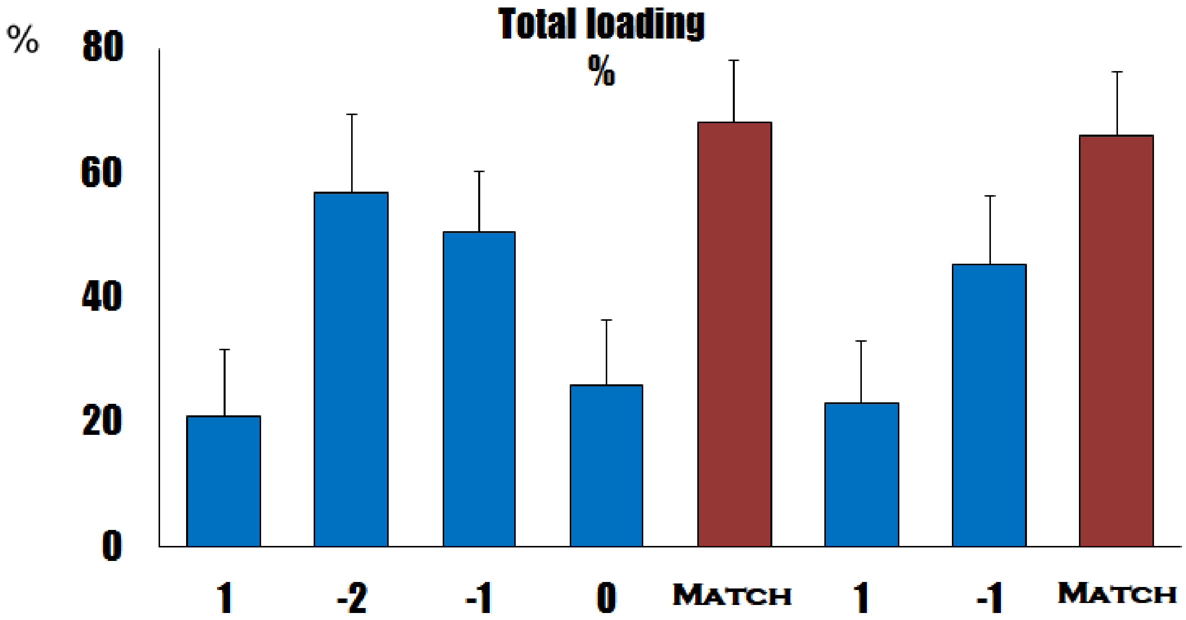
Figure 32



Source: Vázquez-Guerrero et al., 2018.

Another important aspect is that they established the load dynamics during training before the match day.

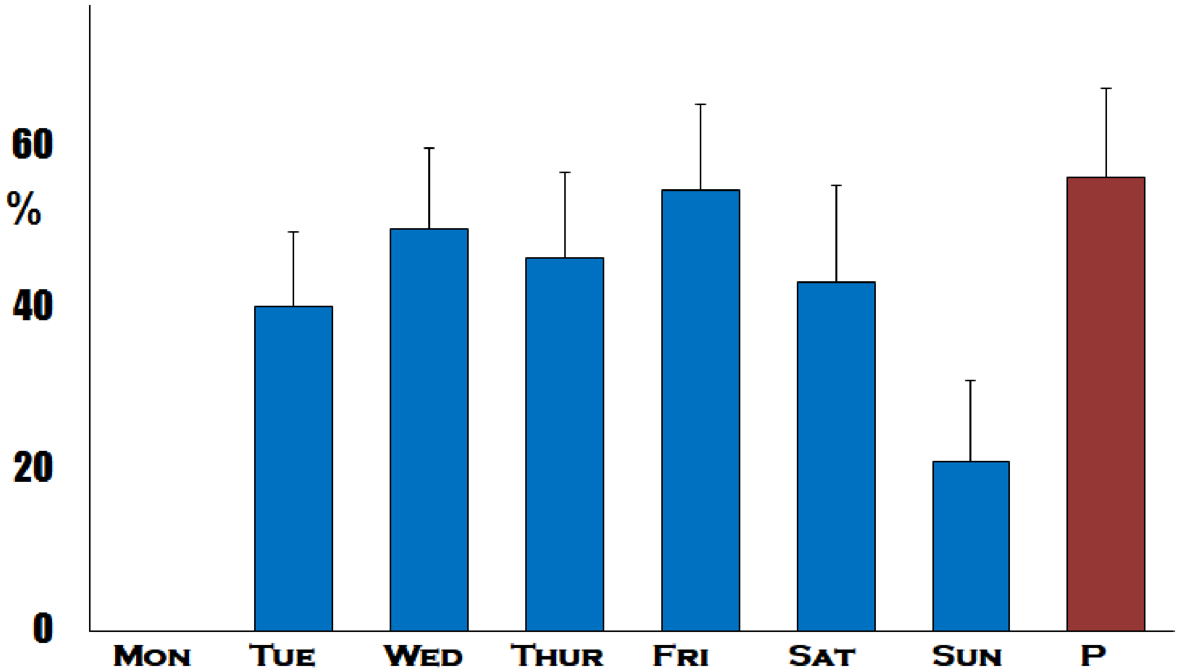
Figure 33



Source: Vázquez-Guerrero et al., 2018.

The same was done when it was about a microcycle of two matches or when only one match a week was played.

Figure 34



Source: Vázquez-Guerrero et al., 2018.

References

Beato, M., De Keijzer, K., Carty, B. and Connor, M. (2019). Monitoring Fatigue During Intermittent Exercise With Accelerometer-Derived Metrics. *Frontiers in Physiology, 10.* doi:10.3389/fphys.2019.00780.

Fox, J., Stanton, R. and Scanlan, A. (2018). A Comparison of Training and Competition Demands in Semiprofessional Male Basketball Players. *Research quarterly for exercise and sport*, 89(1), pp. 103-111. doi: 10.1080/02701367.2017.1410693.

Gómez-Carmona, C., Bastida-Castillo, A., García, J., Ibáñez, S. and Pino Ortega, J. (2018). Static and dynamic reliability of WIMU PRO™ accelerometers according to anatomical placement. *Proceedings of the Institution of Mechanical Engineers Part P Journal of Sports Engineering and Technology*. DOI: 10.1177/1754337118816922.

Lam, W. K., Liebenberg, J., Woo, J., Park, S. K., Yoon, S. H., Tsz-Hei Cheung, R. and Ryu, J. (2018). Do running speed and shoe cushioning influence impact loading and tibial shock in basketball players? *PeerJ*. DOI 10.7717/peerj.4753.

Lucas, L., England, B., Mason, T., Christopher, L., Taylor, M., Alexander, M. and Thomas, A. (2018). Decision-Making Influences Tibial Impact Accelerations During Lateral Cutting. *Journal of Applied Biomechanics*, 34(5), pp. 414-418. DOI: https://doi.org/10.1123/jab.2017-0397.

McClay, I., Robinson, J., Andriacchi, T., Frederick, E., Gross, T., Martin, P., Valiant, G., Williams, K., and Cavanagh, P. (1994). A Profile of Ground Reaction Forces in Professional Basketball. *Journal of applied biomechanics*, 10, pp. 222-236.

Montgomery, P., Pyne, D. and Minahan, C. (2010). The Physical and Physiological Demands of Basketball Training and Competition. *International journal of sports physiology and performance*, 5, pp. 75-86. DOI: 10.1123/ijspp.5.1.75.

Peterson, K. D., and Quiggle, G. T. (2016). Tensiomyographical responses to accelerometer loads in female collegiate basketball players. *Journal of Sports Sciences*, 35(23), pp. 2334–2341. doi:10.1080/02640414.2016.1266378.

Scanlan, A., Wen, N., Tucker, P. and Dalbo, V. (2014). The Relationships Between Internal and External Training Load Models During Basketball Training. *Journal of strength and conditioning research / National Strength & Conditioning Association*, 28(9), pp. 2397-2405. DOI: 10.1519/JSC.0000000000000458.

Scanlan, A.., Fox, J. L., Milanović, Z., Stojanović, E., Stanton, R., and Dalbo, V. J. (2019). Individualized and Fixed Thresholds to Demarcate PlayerLoad Intensity Zones Produce Different Outcomes. *Journal of Strength and Conditioning Research*, 1. doi:10.1519/jsc.0000000000003001.

Staunton, C., Wundersitz, D., Gordon, B. and Kingsley, M. (2017). Construct Validity of Accelerometry-Derived Force to Quantify Basketball Movement Patterns. *International Journal of Sports Medicine*, 38(14), pp. 1090-1096. DOI: 10.1055/s-0043-119224.

Svilar, L., Castellano, J., Jukic, I. and Casamichana, D. (2018). Positional Differences in Elite Basketball: Selecting Appropriate Training - Load Measures. *International Journal of Sports Physiology and Performance*, 13, pp. 1-24. DOI: 10.1123/ijspp.2017-0534.

Vázquez-Guerrero, J., Suarez-Arrones, L., Casamichana, D. and Rodas, G. (2018). Comparing external total load, acceleration and deceleration outputs in elite basketball players across positions during match play. Kinesiology. 50(2). DOI: 10.26582/k.50.2.11.

Wei, Q., Wang, Z., Woo, J., Liebenberg, J., Park, S. K., Ryu, J. and Lam, G. (2018). Kinetics and perception of basketball landing in various heights and footwear cushioning. *PLoS ONE*, 13(8), pp 1-9. https://doi.org/10.1371/journal.pone.0201758.