BARÇA INNOVATION HUB
Universitas

PHYSICAL DEMANDS AND INJURY RISKS TEAM SPORTS

Module 4: Application of inertial systems in different tests in team sports

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In this module, we will expose the different useful tests for monitoring the training process through one or more seasons. These allow us to learn and evaluate the state of the player different systems and, at the same time, detect the evolution and variations on performance. This way, the club will clarify which actions might optimize performance from a conditional perspective.

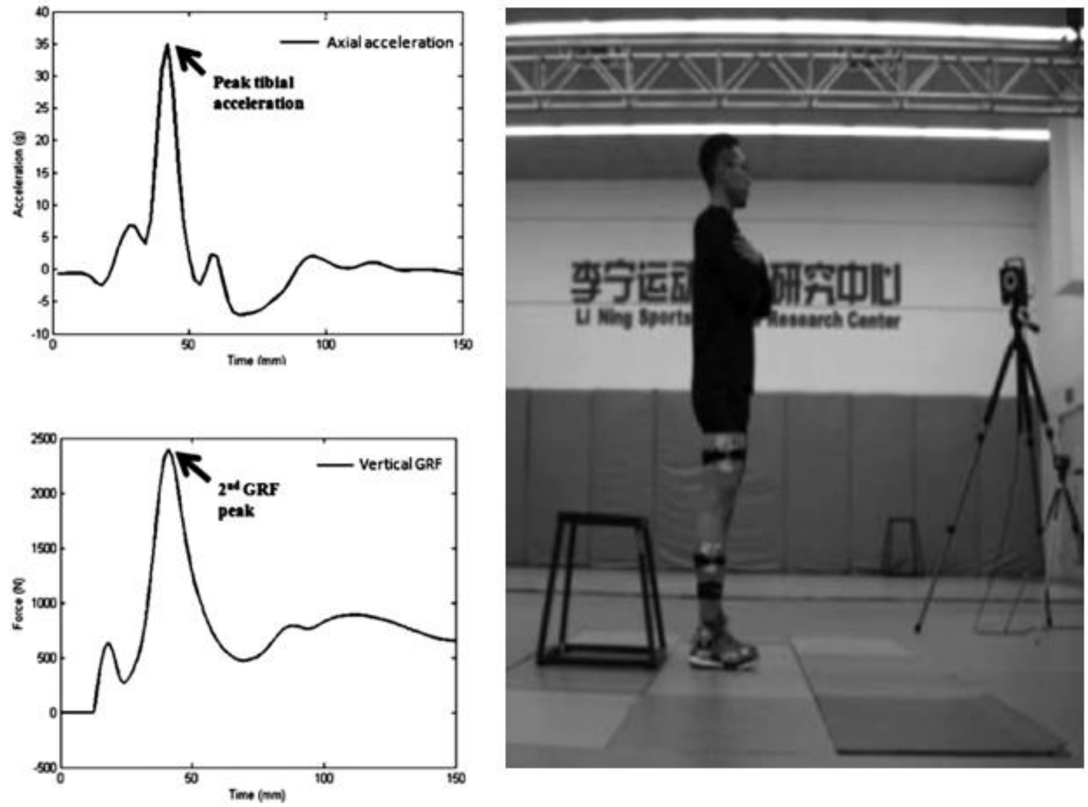
The evaluation process, as well as its later interpretation, has to involve the coaching staff, the medical staff and, of course, the trainer.

A basketball player could be evaluated on the court, during sports practice and in more specific circumstances related to this end. Some aspects that could be considered indirectly or approximately by applying this technology are: proprioception, fatigue, core stability, force and power, movement range, neuromuscular control and fitness level.

In order to trust the data provided by measurement systems it is important to determine its validity. This way, they are measured in force platforms, not only in the impulse stage, but also in the players' landing stage, when they do a vertical jump. The force platform is, in this case, the gold standard. The IMUs validity for these types of measures is established this way.

In figure 1, we can see as Wing Kai Lam and its collaborators (2015) compared the ground reaction force produced in a drop jump, using a force platform, with the estimation for the tibia acceleration peak on landing. A very similar behavior is observed in both graphics.

Figure 1: Comparison of a vertical jump done in a force platform and with an inertial system

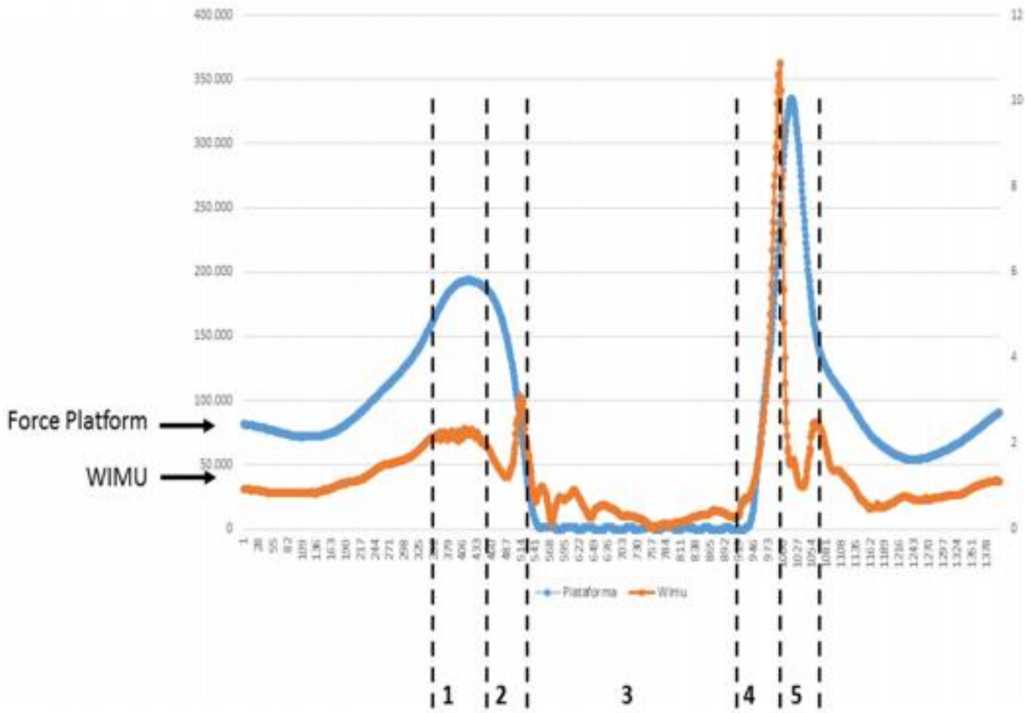


Source: Lam et al., 2015, p. 22.

It is established this way that this inertial system is adequate for impacts typical for a jump landing.

Once this information is contrasted, the next step is to guarantee that the system used in FC Barcelona is valid and reliable. These inertial devices, called Wireless Inertial Movement Unit (WIMU) owned by Real Track Systems were proven valid and reliable in a vertical jump. In figure 2 they show a very similar behavior to gold standard taken with the force platform and the result obtained with the WIMU device.

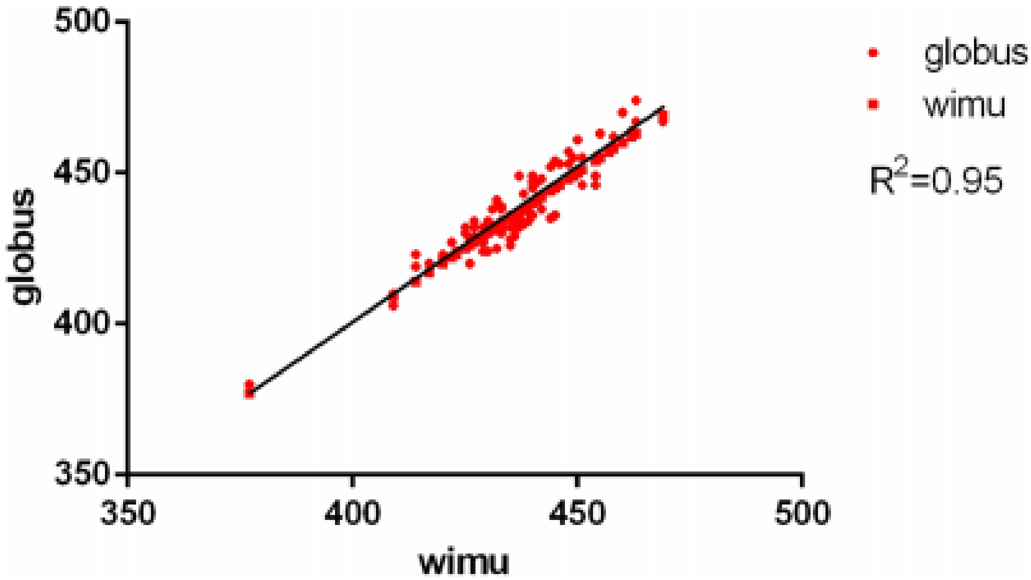
Figure 2: Comparison of the register of a jump done in a force platform and another done with an inertial device (WIMU)



Source: Ortega, García-Rubio e Ibáñez, 2018, p. 4.

The curves are very similar, which has a positive effect in the device validation. The correlation between the data provided by both systems is almost perfect and it is established in 0, 95.

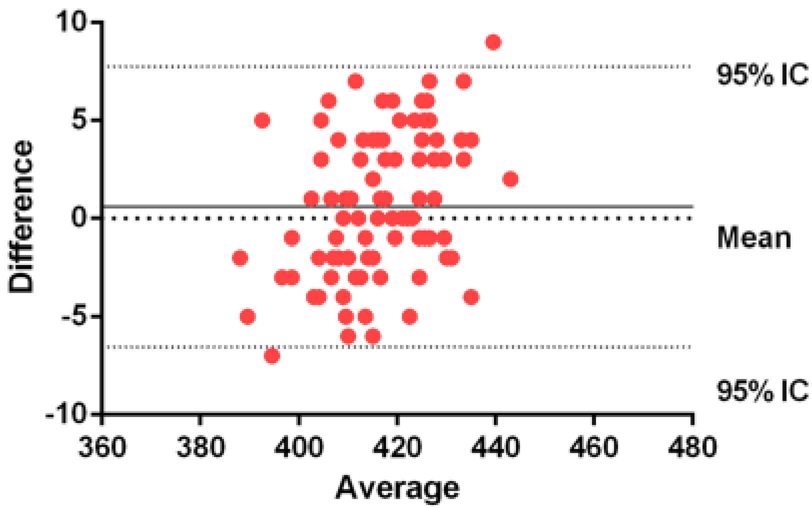
Figure 3: Graphic of correlation between WIMU and the force platform in the evaluation of vertical jump (Counter Movement Jump or CMJ)



Source: Ortega et al., 2018, p. 6.

Figure 4 shows a Bland-Altman statistical analysis that determines the test´s reliability, in this case, for the test for the vertical jump with countermovement (CMJ).

Figure 4: Graphic for CMJ jump test reliability with a WIMU device

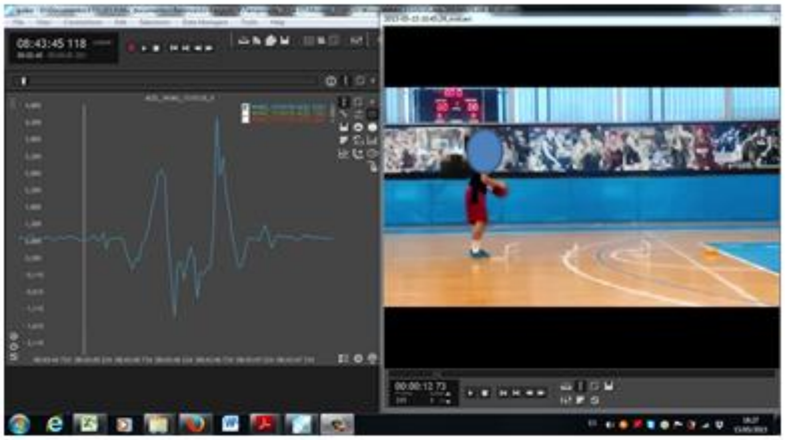


Source: Ortega et al., 2018, p. 7.

This way, the WIMU system is verified as valid and reliable to measure the jump.

In figure 5, we observe the practical application of the WIMU test on court, for measuring a basket shot. In the image they show the dynamics of the jump the player does when executing a basket shot. In the test they add a conditioner for the execution: they put some fences to force the player to overcome a certain height.

Figure 5: Dynamics of the jump with acceleration in real time

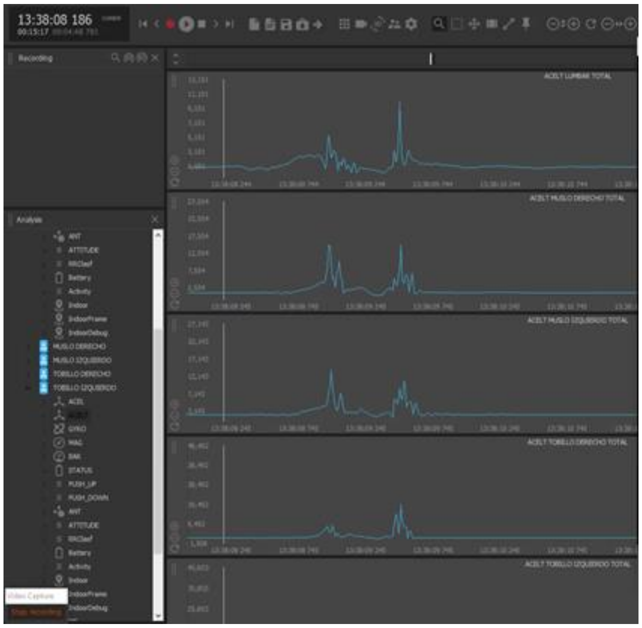


Source: Own production with WIMU devices, Realtrack Sytems S.L.

This way, the device provides a real time feedback of the jumps. This is especially useful for optimizing players' performance landing, since landings generally require high intensity impacts for its relation with injuries.

Below, an analysis is made on a jump over a fence, registered by various WIMU devices distributed in different anatomic body zones (the ankle, the knee, the lower back and the upper back). This is the way they do the jump and they analyze its impact on the different parts of the body in which the devices were placed (figure 6).

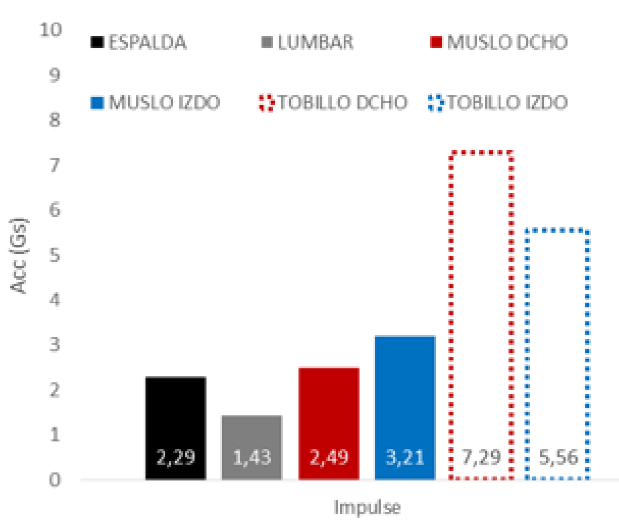
Figure 6: Acceleration of a jump in different anatomic zones to evaluate its kinematics using inertial sensors



Source: Own production with WIMU devices, Realtrack Sytems S.L.

Figure 7 describes the dynamics of this jump registered by each of the sensors placed on the shown zones. With this method, for example, we can measure acceleration of the different zones in G´s. The part that supports the load the most is the ankle, not only in the impulse, but also on landing. Therefore, we can establish the differences between both limbs when jumping, in the impulse stage and in the landing one.

Figure 7: Acceleration measured during jump in different anatomic zones

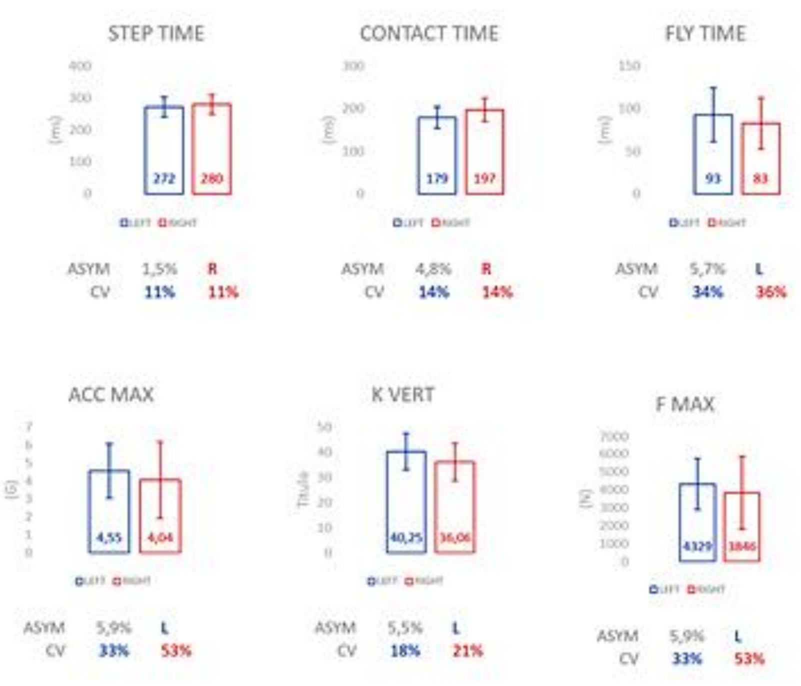


Espalda	Back
Lumbar	Lower back
Muslo dcho	Right thigh
Muslo izdo	Left thigh
Tobillo dcho	Right ankle
Tobillo izdo	Left ankle

Source: Own production (together with Xavi Reche) with WIMU devices, Realtrack Sytems S.L.

Furthermore, these systems allow analysis of impacts during sprint. Figure 8 shows a report generated by the WIMU system, in which impacts are analyzed in a lineal sprint.

Figure 8: Results of measuring a lineal sprint



Source: Own production (together with Xavi Reche) with WIMU devices, Realtrack Sytems S.L.

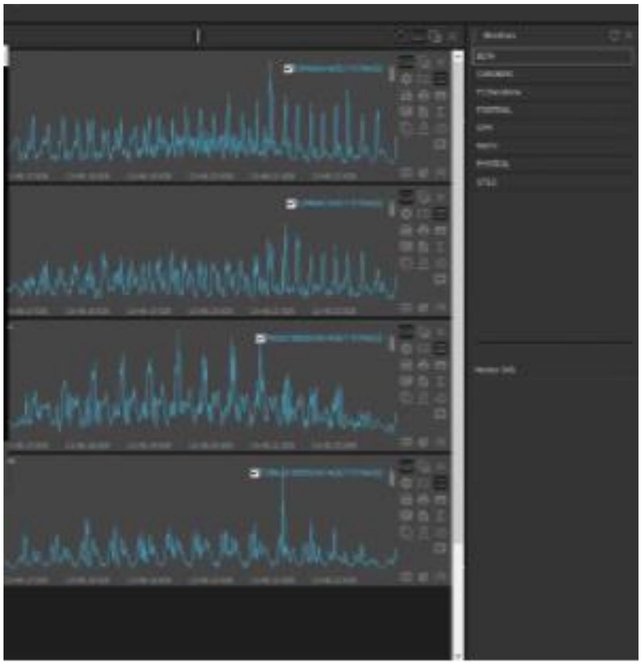
The variables analyzed are: step time, contact and fly time, maximum acceleration and force. Besides, vertical stiffness is established, which allows to differentiate the performance of both limbs. This way, the percentage value of the symmetry and the coefficient of variation are established.

Another test made is the Course Navette one. It is applied for 8 minutes, only to learn about the player submaximal aerobic resistance. WIMU devices, besides measuring heart rate during test, allow doing the step test to measure the behavior of both limbs, just as we have shown in the sprint example.

Furthermore, we can also analyze the player vertical stiffness in response to particular training or competition stimuli and establish if there are differences induced by fatigue. Our evidences (unpublished data) show that stiffness behavior could help in detecting fatigue.

Figure 9 reflects the acceleration at a maximum speed sprint (sensors were located in the same anatomic zones indicated in the previous figure).

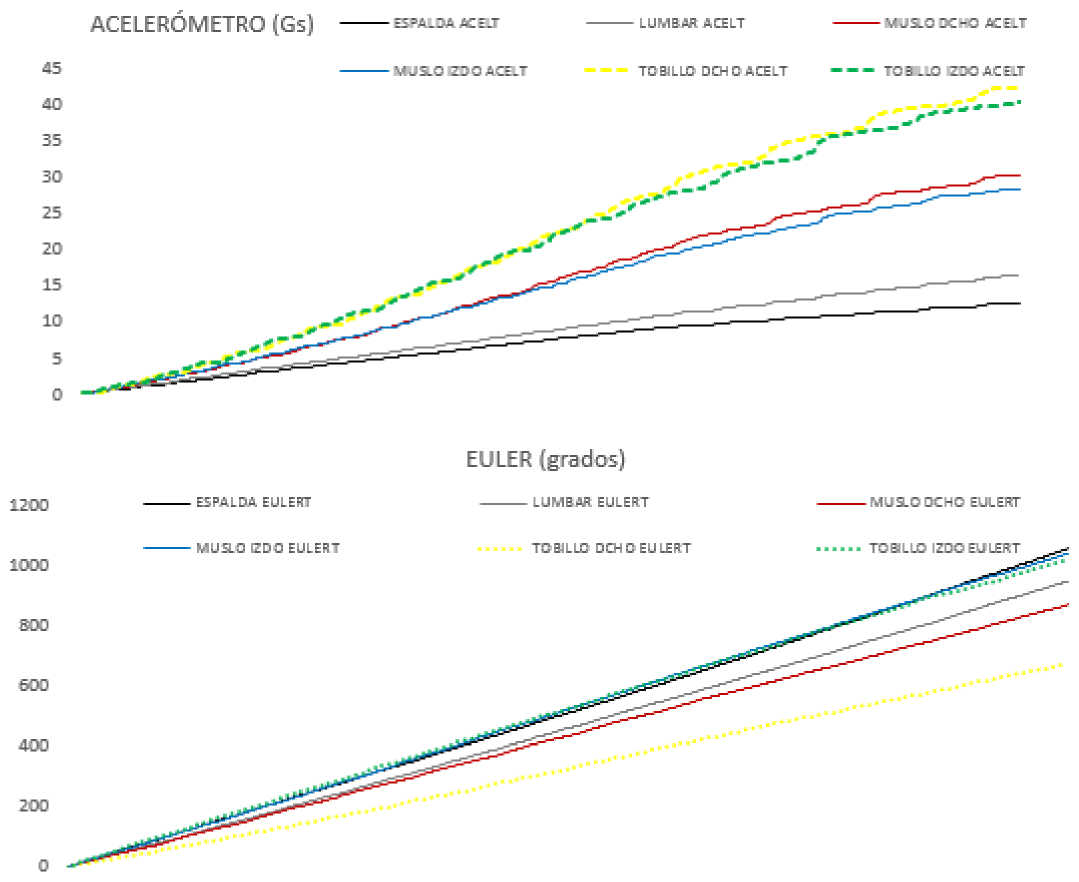
Figure 9: Behavior of acceleration in different anatomic zones during a maximum speed sprint



Source: Own production (together with Xavi Reche) with WIMU devices, Realtrack Sytems S.L.

This data (figure 10) analysis, where acceleration measured in G´s is compared, shows minimum differences among the same anatomic zones in both limbs. However, these differences are considerable and, therefore, relevant.

Figure 10: Comparison by acceleration and Euler (grades) of behavior among the different anatomic zones during the maximum speed race



Acelerómetro (G´s)	Accelerometer (G´s)
Espalda ACELT	Back ACELT
Lumbar ACELT	Lower back ACELT
Muslo dcho ACELT	Right thigh ACELT

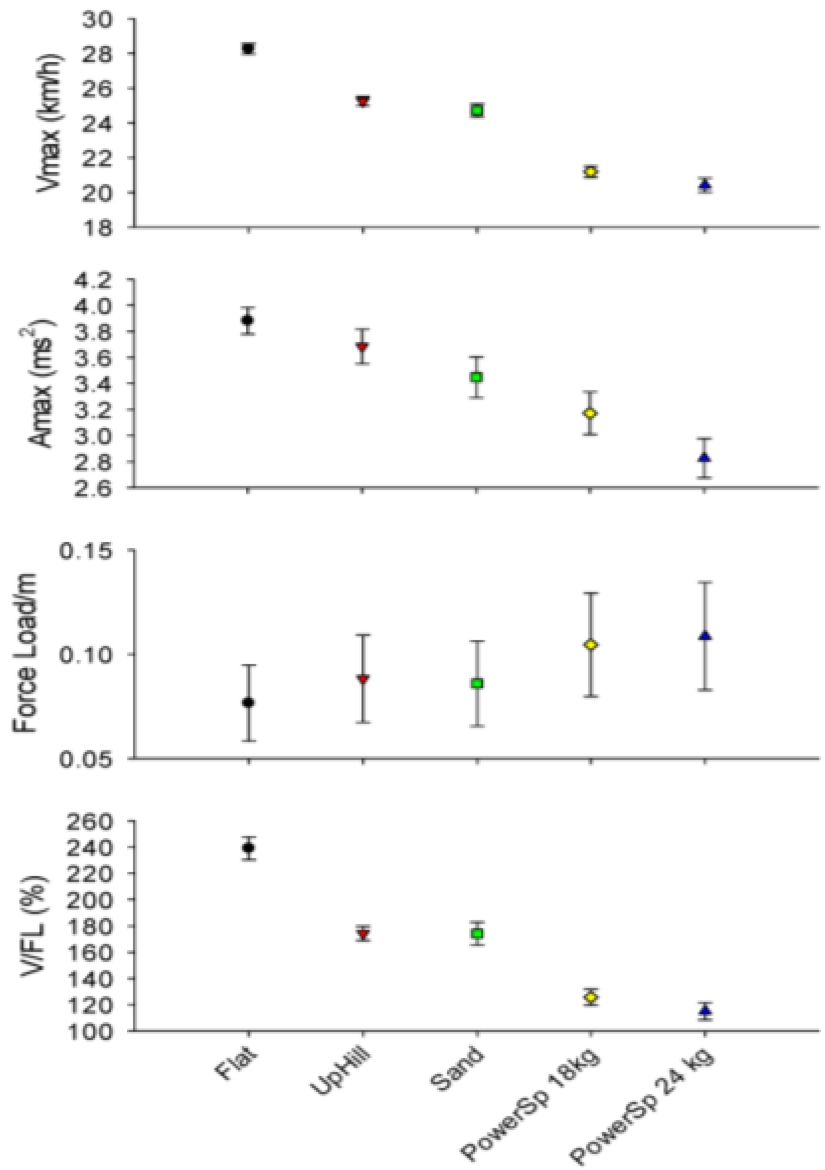
Muslo izdo ACELT	Left thigh ACELT
Tobillo dcho ACELT	Right ankle ACELT
Tobillo izdo ACELT	Left ankle ACELT
Euler (grados)	Euler (grades)
Espalda EULERT	Back EULERT
Lumbar EULERT	Lower back EULERT
Muslo dcho EULERT	Right thigh EULERT
Muslo izdo EULERT	Left thigh EULERT
Tobillo dcho EULERT	Right ankle EULERT
Tobillo izdo EULERT	Left ankle EULERT

Source: Own production (together with Xavi Reche) with WIMU devices, Realtrack Sytems S.L.

The difference in grades between both ankles corresponds, very likely to a dorsiflexion deficit in one of them. Gómez-Carmona and collaborators in 2019 validate using these devices for these types of measurement. Again, proposed tests are supported by scientific literature.

For their part, Buchheit and Simpson (2017) carried out an analysis about the 15 meters sprint under different conditions: a flat surface, a surface with a 4% hill, a sand surface and a machine with 18 kg and 24 kg resistance that simulated sprint. They looked the variable that was heavier in each of the surfaces and that way, for example, not only the maximum speed, but also the maximum acceleration were reached in the flat 15 meters sprint. However, force was the strongest in the last of the proposed conditions (resistance machine with two different loads).

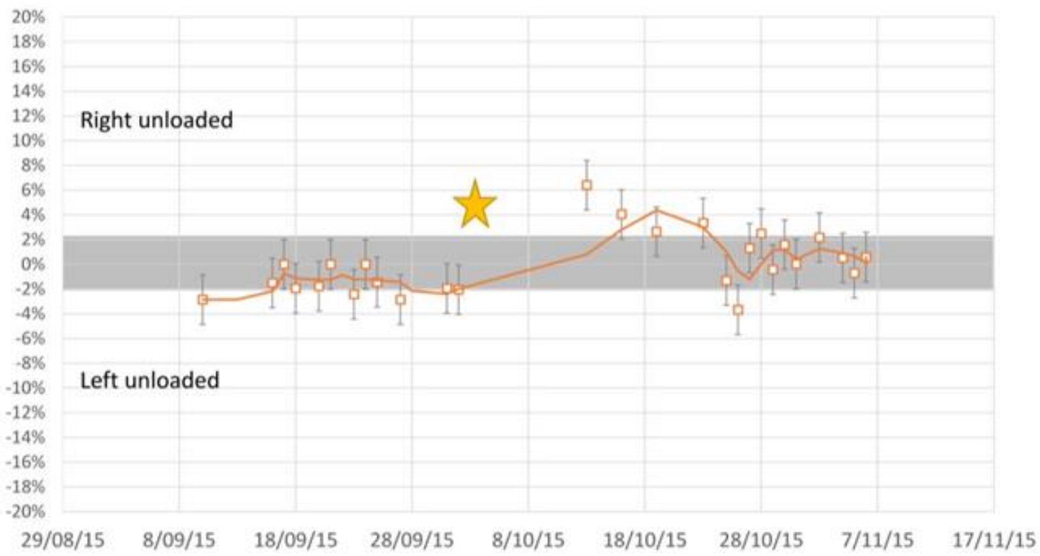
Figure 11: Analysis of a 15 meters sprint under different conditions



Source: Buchheit y Simpson, 2017, p. 39.

Another practical application for these devices is the analysis of a training task or session of a player that has suffered an ankle injury. This way, a comparison is made between previous injury data with current one under similar conditions, obtained during the readaptation process. Figure 12 shows how the studied player supported a similar load in both ankles before the injury. However, right after injury, it is observed that the injured right ankle produces less force (reduction of the supported load) in relation to the one that is not injured. Later, the evolution of the return to play process allows stabilization of force production (supported load) in both limbs.

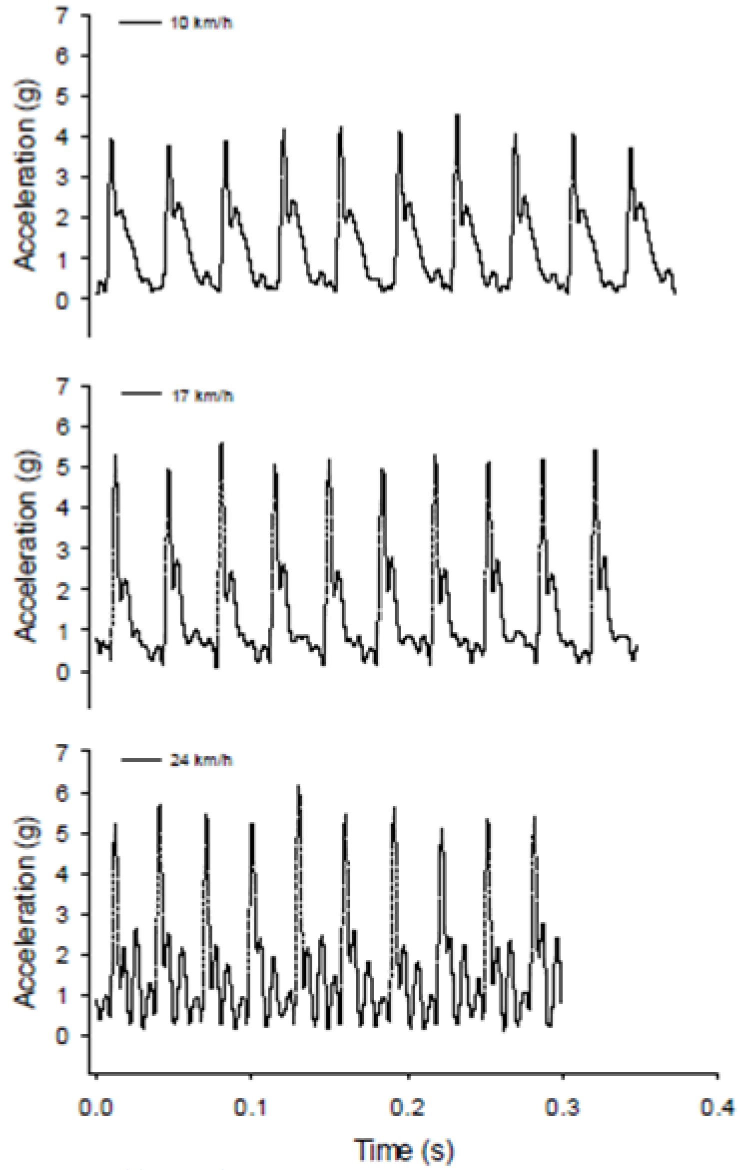
Figure 12: Differences in supported load on lower limbs on a player with an ankle injury



Source: Buchheit y Simpson, 2017, p. 40.

Another interesting publication of the same author (Buchheit, Gray and Morín, 2015) analyses ten sprint steps in three different speed intensities, using inertial systems.

Figure 13: Analysis of acceleration in G´s of the sprint under different intensities

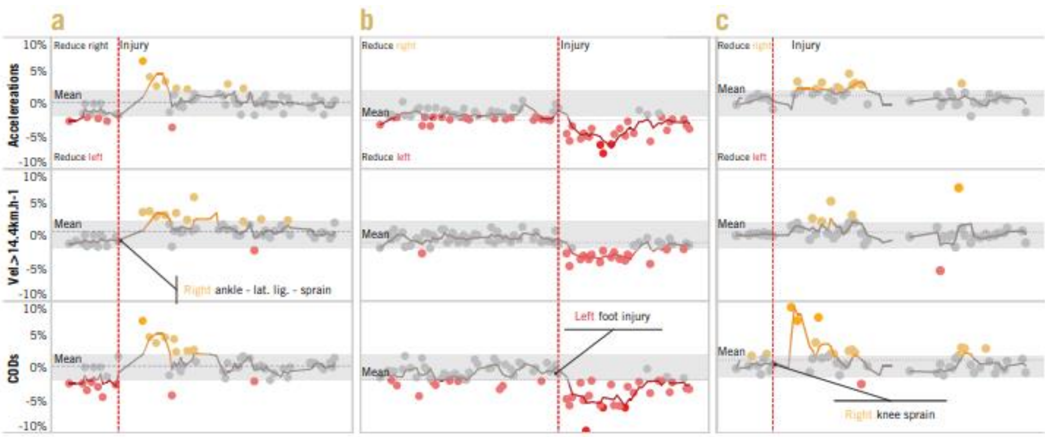


Source: Buchheit et al., 2015.

This study´s main conclusion is that inertial systems allow assessment of the contact time and the vertical stiffness during sprint. Besides, they allow monitoring neuromuscular fatigue and performance in sports based on sprint.

In another publication, Lacome, Simpson and Buchheit (2018) use these systems to monitor and evaluate adaptations done before, during and after a process of readaptation to competition on different types of injuries. To this end, they analyze different variables, like distance, high intensity speed and changes in direction (figure 14).

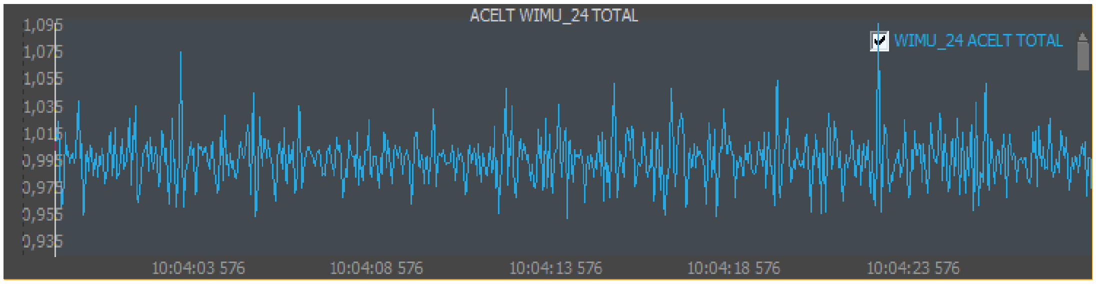
Figure 14: Examples of the evolution of asymmetry in different variables before, during and after injury



Source: Lacome, Simpsons y Buchheit, 2018, p. 62.

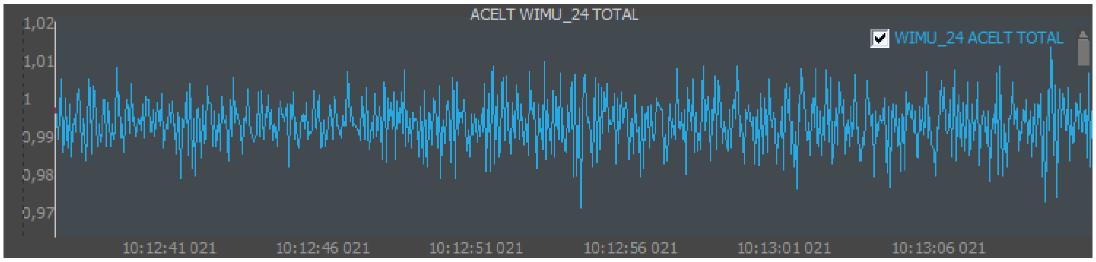
Besides the presented tests, inertial devices allow estimation of the core stability. Different core exercises were made and the coefficient of variation (CV) was calculated from the signal of the total acceleration. This way, a number was established and that number indirectly showed the stability required for this exercise: when the result was bigger, the exercise was more challenging for the core (figure15).

Figure 15: Coefficient of variation of a core stability exercise done on all fours



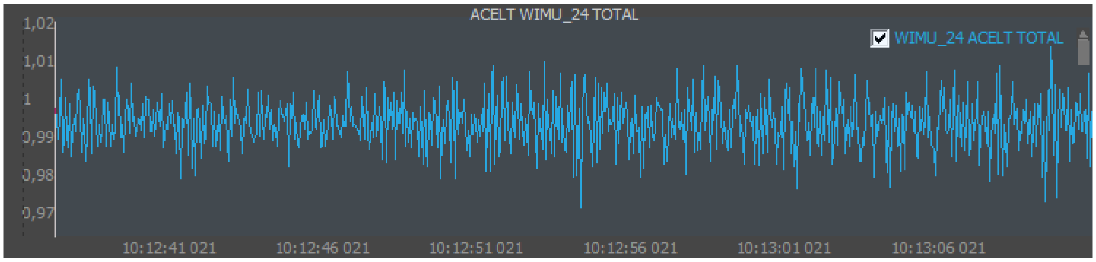
Source: Own production with WIMU devices, Realtrack Sytems S.L.

Figure 16: Coefficient of variation of a front plank



Source: Own production with WIMU devices, Realtrack Sytems S.L.

Figure 17: Coefficient of variation of a side plank



Source: Own production with WIMU devices, Realtrack Sytems S.L.

Figure 15 shows the coefficient of variation (CV = 1, 74) of a low intensity core stability exercise done on all fours. Figure 16, on the other hand, shows a progression of the previous exercise (front plank) and it gets a CV = 0, 64. Figure 17 displays the CV behavior in the side plank, which shows a value of 0, 91. This way, it is possible to establish an objective progression for the core challenge. Again, scientific literature helps us to endorse the usage of inertial systems to analyze different elements, in this case, trunk stability (Bastida-Castillo, Gómez-Carmona, Reche-Soto, Granero-Gil y Pino Ortega, 2018).

This same idea is applied in CV to measure stability and balance in different exercises and to establish the challenge level for each of them (1 or 2 supports, using destabilizing material, modification of the gravity center, etc.). In this case, there is still no scientific evidence.

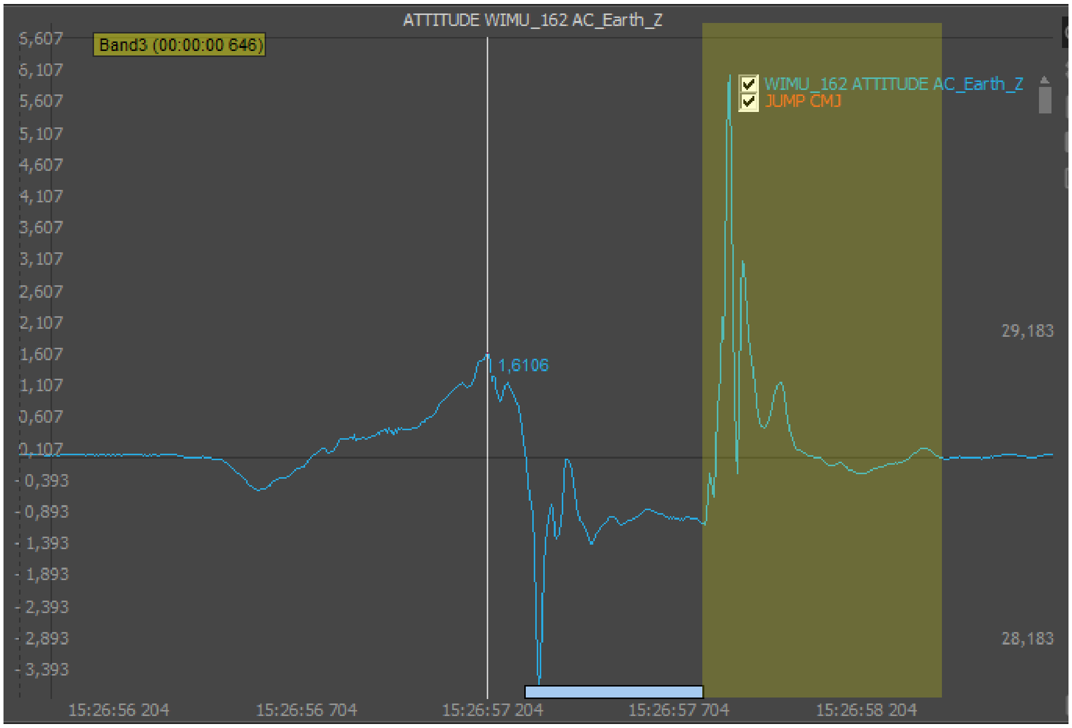
Likewise, movement range can be measured either by doing a hip flexion or an ankle dorsiflexion. This helps determining the range of motion. The hip flexion test has also been studied using inertial systems, like in the case of Muyor in 2017.

The next step (figure 18) measures the dynamic stability of landing on one leg in a jump (CMJ). What is measured here is the time necessary for stabilization, after the jump is executed. Besides allowing the detection of possible deficits in stabilization capacity, this check helps in the injury readaptation process. This test does not have scientific validity.

These devices can also measure the following elements:

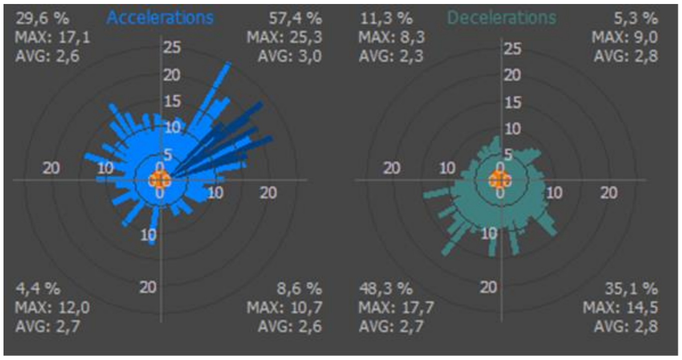
- the force used in changes of direction and possible limbs deficits, as well as the comparison of the values among the different players that do the same task;
- the force used in a squat done on a Smith machine with different loads, making a difference between the concentric and eccentric phase;
- the number of accelerations and decelerations in different intensity zones (figure 19) and
- mechanical load of a player running on treadmill in different intensities (figure 20).

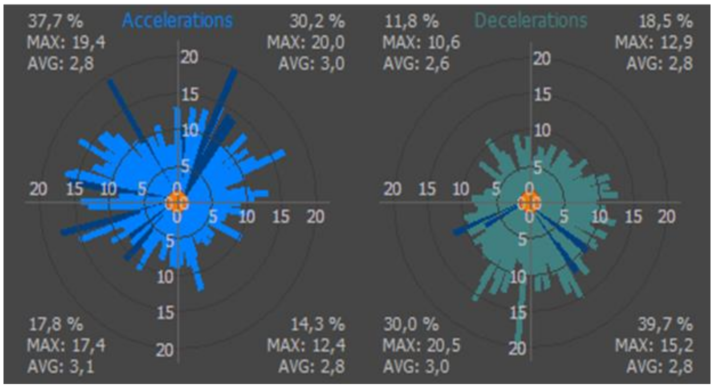
Figure 18: Landing dynamic stability (period until stabilization) on a leg in a CMJ jump



Source: Own production with WIMU devices, Realtrack Sytems S.L.

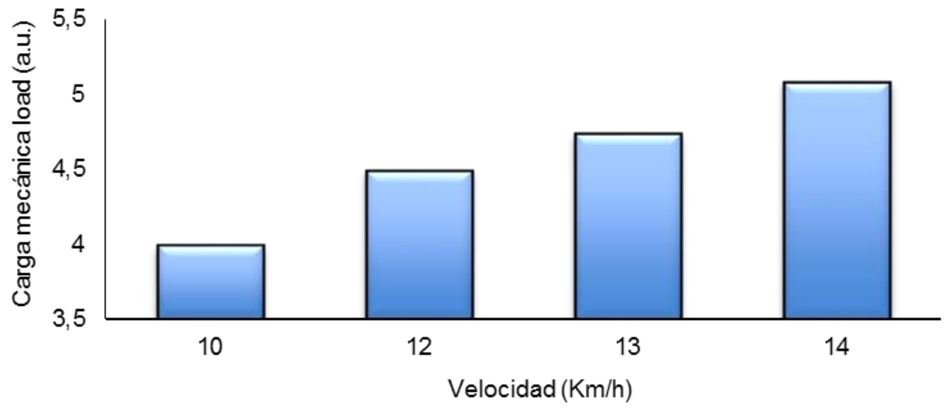
Figure 19: Accelerations and decelerations in a technical and tactical session of a player in a readaptation to competition stage





Source: Own production with WIMU devices, Realtrack Sytems S.L.

Figure 20: Mechanical load in a sprint on a treadmill at different intensities in the player readaptation to competition stage



Carga mecánica	Mechanical load
Velocidad (km/h)	Speed (km/h)

Source: Own production with WIMU devices, Realtrack Sytems S.L.

Referencias

Bastida-Castillo, A., Gómez-Carmona, C., Reche-Soto, P., Granero-Gil, P. y Pino Ortega, J. (2018). Valoración de la estabilidad del tronco mediante un dispositivo inercial - Trunk stability assesment using an inercial device. *Retos: nuevas tendencias en educación física, deporte y recreación*, 33, 199-203.

Buchheit, M., & Simpson, B. M. (2017). Player-Tracking Technology: Half-Full or Half-Empty Glass? *International Journal of Sports Physiology and Performance*, 12(2), 35-41. doi: 10.1123/ijspp.2016-0499

Buchheit, M., Gray, A. & Morin, J. B. (2015). Assessing Stride Variables and Vertical Stiffness with GPS-Embedded Accelerometers: Preliminary Insights for the Monitoring of Neuromuscular Fatigue on the Field. *©Journal of Sports Science and Medicine*, 14, 698-701. Recovered from http://www.jssm.org

Gómez-Carmona, C. D., Bastida-Castillo, A., González-Custodio, A., Olcina, G. & Pino-Ortega, J. (2019). Using an Inertial Device (WIMU PRO) to Quantify Neuromuscular Load in Running: Reliability, Convergent Validity, and Influence of Type of Surface and Device Location. *Journal of Strength and Conditioning* Research 00(00)/1–9ª. National Strength and Conditioning Association.

Lacome, M., Simpson, B. & Buchheit, M. (2018). 2018 Monitoring training status with player-tracking technology. *Still on the road to Rome* (Part 1), 55-63.

Lam, W. K., Woo, J., Liebenberg, J. N., Cheung, J., Ryu, P. J., Yoon, S., & Park, S. K. (2015). Tibial accelerations and ground reaction forces in basketball shoes from different landing heights. *Footwear Science,* 7(1), 21–23. doi: 10.1080/19424280.2015.1036941

Muyor, J. (2017). Validity and Reliability of a New Device (WIMU®) for Measuring Hamstring Muscle Extensibility. *International Journal of Sports Medicine*, 38(09), 691–695. doi: 10.1055/s-0043-108998

Pino-Ortega, J., García-Rubio, J., & Ibáñez, S. J. (2018). Validity and reliability of the WIMU inertial device for the assessment of the vertical jump. *PeerJ*, 6, e4709. doi: 10.7717/peerj.4709