EBOOK: PART II

Testing and Monitoring Gait Performance

Understand how biomechanics professionals can use plantar pressure measurement systems for gait assessments, return-to-play decisions, and biofeedback.

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XSENSOR | Intelligent Dynamic Sensing

Intro to Plantar Pressure Mapping in Sport (Part II)
Testing and Monitoring Gait Performance
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Introduction

A wide range of biomechanics professionals — such as strength and conditioning coaches, physiotherapists, athletic trainers, sports scientists — and professional sports players require a comprehensive approach to understanding movement in order to maximize human performance. Developing gait assessment strategies that use specialized technology like plantar pressure measurement systems can help achieve this. Plantar pressure mapping can be used to create individual performance profiles for athletes, which means gait training programs can be individualized, fatigue can be monitored, and strengths and weaknesses can be identified.[1]

Understanding the Assessment Process

In professional sports, often terms like *assessment, measurement, analysis,* and *monitoring* are used interchangeably to define the process of performing and administering specific tests to athletes. However, a complete biomechanical assessment is made up of several levels and each term has a precise meaning — it represents a specific method with a well-defined role in the overall assessment process.

The first level in a quantitative assessment of human movement is the **measurement phase**, which is the result of both direct observation and the use of technology to obtain data on specific movement patterns and skills.

The second level is the **description phase**, where the data obtained from the measurement can be transformed from raw data into information, such as running speed and jump height. It's important to note that monitoring is included in the description phase, as it represents the tracking of changes over time.

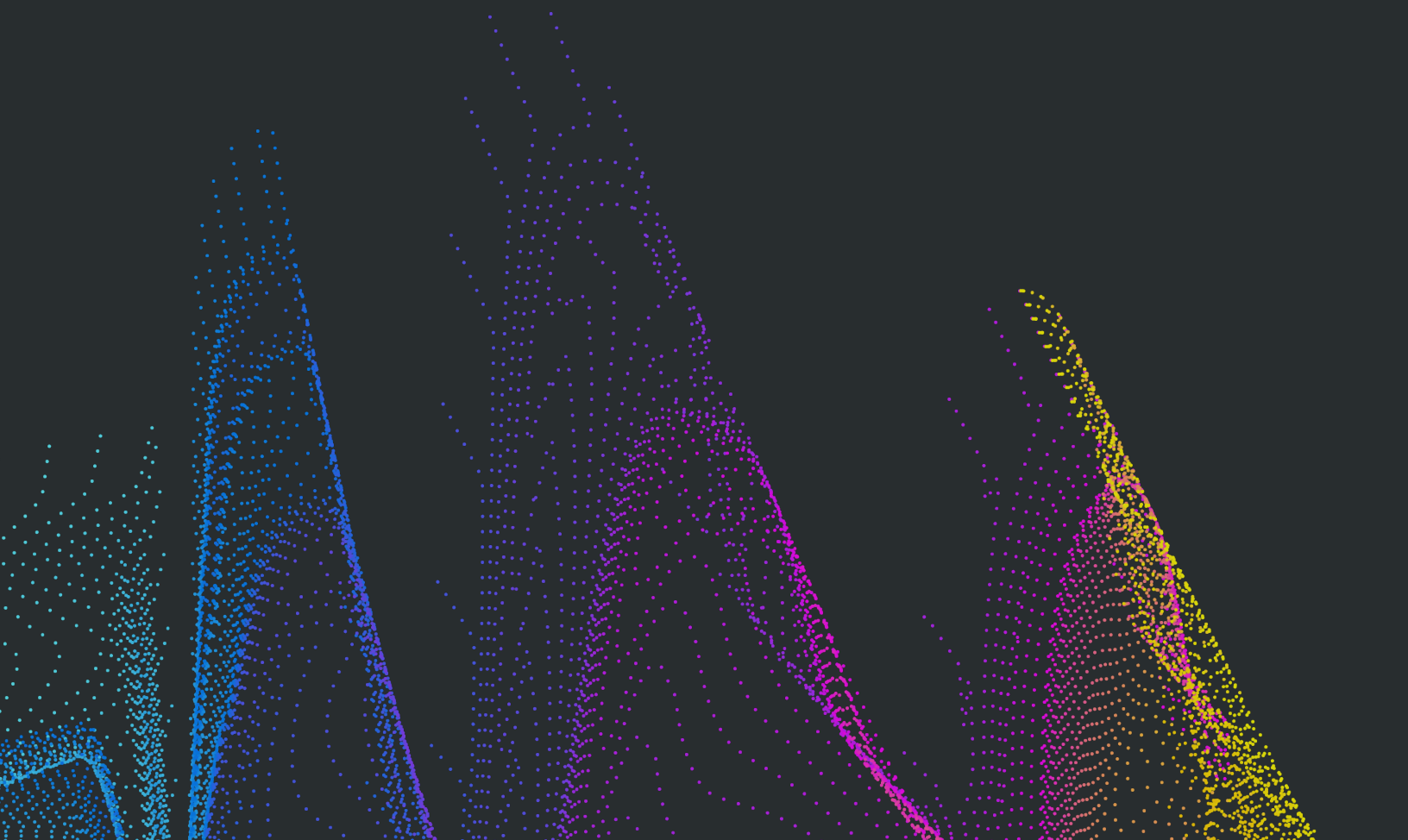
The third and final level of assessment is the **analysis phase**, where all the data obtained from the previous levels is calculated and made visual, so it can be interpreted and evaluated.[2]

These three levels of assessment inform the decision-making of biomechanics professionals to individualize training programs and develop rehabilitative strategies. Because we're focused on plantar pressure mapping in sport, in this ebook we'll be concentrating on the description (monitoring) and analysis phases.

CHAPTER

01.

Using Plantar Pressure Mapping in Gait Assessments



Using Plantar Pressure Mapping in Gait Assessments

The most important datasets used in sport performance evaluations can be categorized into five main groups:

1. Peak Pressure Image
2. CoP Trails/Progression
3. Force-Time and Pressure-Time Curves
4. Cyclogram
5. 4-Box Analysis

It's important to note that plantar pressure mapping technology is not only about determining how much pressure there is, but using pressure data as a starting point to perform a wide variety of biomechanical analyses and evaluations.

Peak Pressure Image

A peak pressure image shows all the peak pressure zones in the sole of the foot during an entire roll-out over the stance phase.

From a qualitative perspective, the peak pressure image can show areas of abnormally high or low pressure, as well as left/right asymmetries. From a quantitative perspective, you can obtain information about weight shift and load distribution over the surface of the foot, as well as foot orientation and axis angle.

Figure 1: Example of a peak pressure image

CoP Trails/Progression

The CoP represents the effect of ground reaction forces (GRF) on a human body in motion — it's a powerful indicator of overall locomotion efficiency (neuromuscular stability and force application). With a plantar pressure measurement system, you can track the CoP path during walking, running, and sprinting, and other movements such as squatting or lunging.

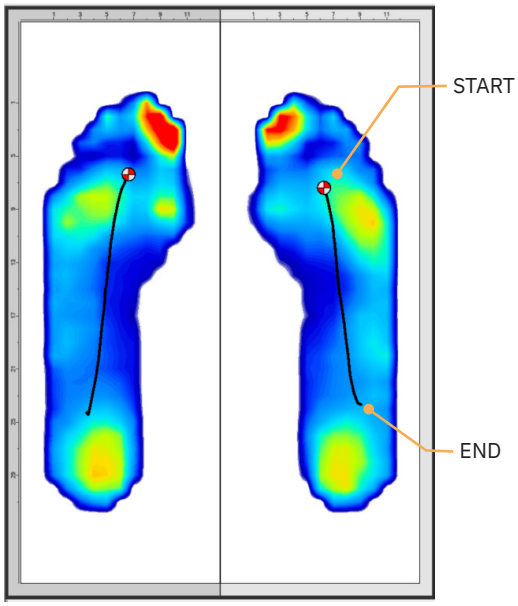


Figure 2: CoP start and end point; CoP trail during foot rollout

There are three aspects to consider when evaluating the progression of the CoP:

1. Trajectory
2. Starting/Ending Point
3. Timing

By trajectory, we mean the shape of the CoP's trail during foot roll-out, reflecting the level of stability and movement efficiency in dynamic activities.

For the starting and ending point, we refer to the point where the CoP begins and ends its progression, as a direct consequence of the dynamics of the foot strike and propulsion.

The timing of CoP progression refers to the time it takes for the CoP to progress over the surface of the foot as well as the velocity of progression: this helps detect asymmetries in bilateral acceleration of the foot and strike dynamics (timing of heel rise and forefoot loading).

Force-Time and Pressure-Time Curves

With information captured from a plantar pressure measurement system, we can evaluate the force-time and pressure-time relationships bilaterally, as well as the duration and magnitude of impact forces and the propulsion phase.

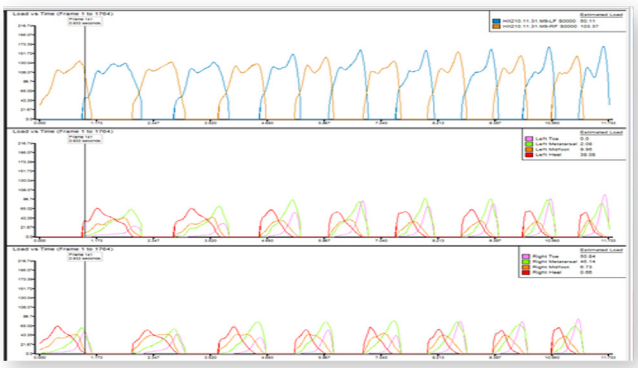


Figure 3: A force-time curve with identification of foot strike, midstance and toe-off

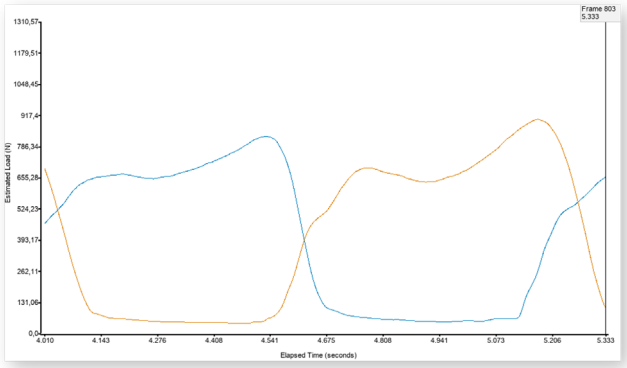


Figure 4: Bilateral comparison of force-time and pressure-time

Cyclogram

The cyclogram or butterfly diagram is a graph showing the course of the CoP during selected consecutive step cycles. The lateral variability is depicted in the y-axis and the anterior-post variability is depicted in the x-axis.

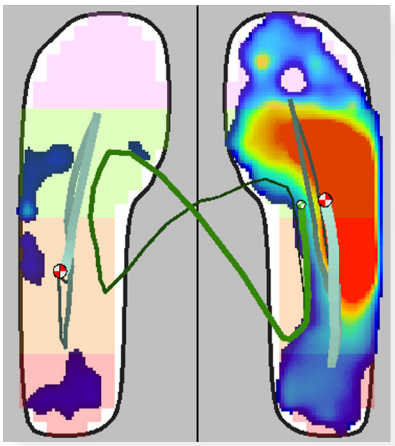


Figure 4: Cyclogram

4-Box Analysis

The 4-box analysis allows the foot to be isolated into regions of interest in order to analyze pressure values and force-time curves individually for each zone (rearfoot, midfoot and forefoot).

Isolating the curves for each foot zone allows coaches to further evaluate foot function and identify specific weak spots in different segments that would otherwise go undetected — even by experienced and skilled biomechanics professionals.

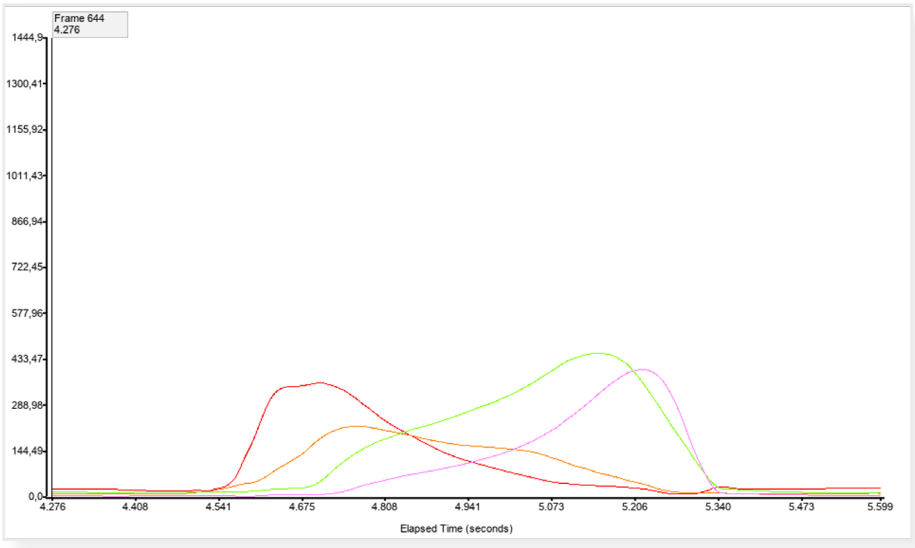
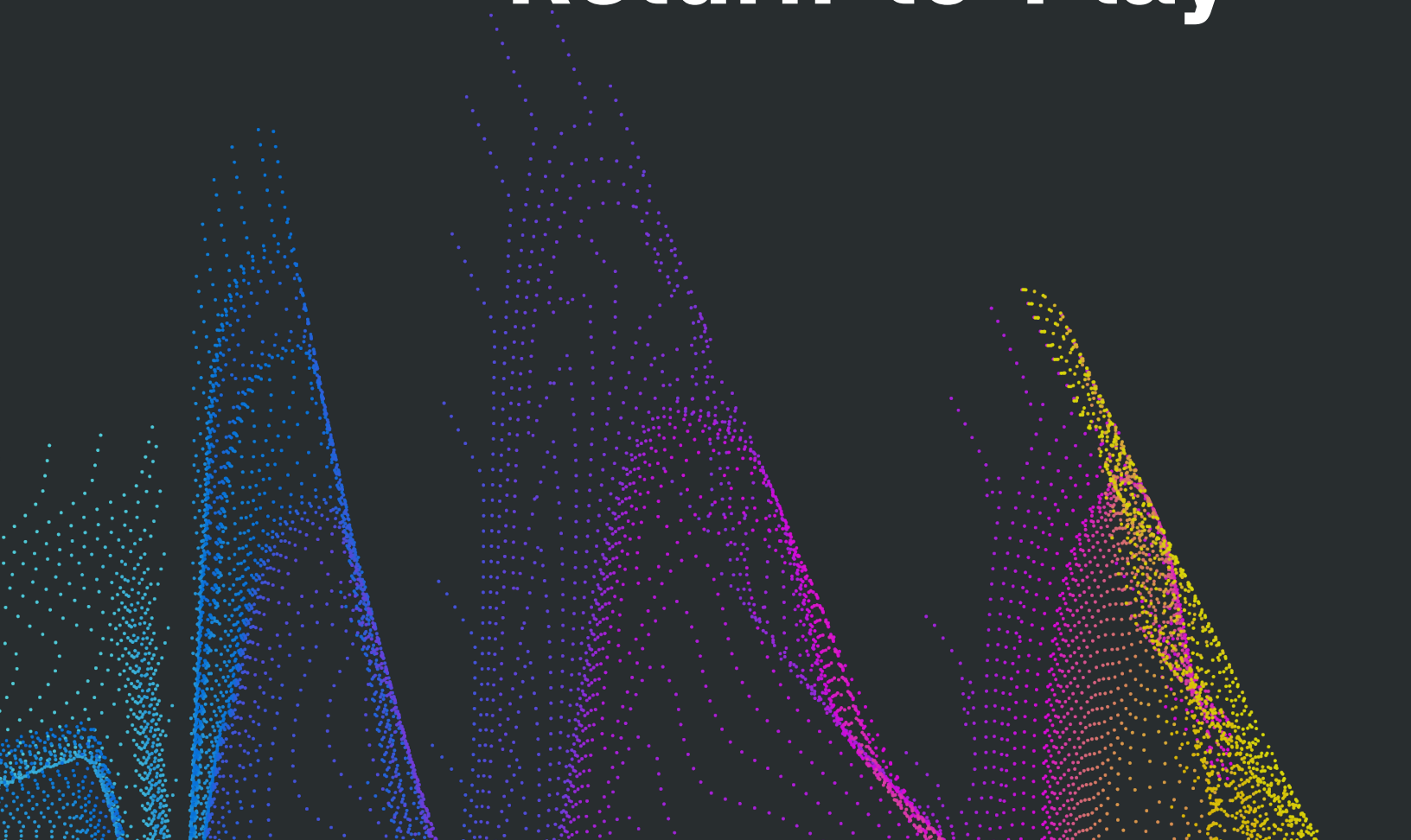


Figure 5: An example of a 4-box analysis with isolated force-time curves for heel, midfoot, metatarsal and toe

CHAPTER

02.

Plantar Pressure Analysis: Injury Risk and Return-to-Play



Plantar Pressure Analysis: Injury Risk and Return-to-Play

One of the biggest advantages of using plantar pressure mapping for sports is that it can be used to monitor rehabilitation and support return-to-play decisions.

As we discussed, monitoring refers to the practice of tracking changes occurring over time. For monitoring to be as effective as possible, it's important to establish an individual baseline profile for each athlete.

What is a Baseline Profile?

A baseline profile identifies changes and deviations from a normal state; in sport, a normal state could be an athlete in healthy condition (i.e. non-injured) or a period of time without any intense training efforts. The main goal of baseline measurements is to allow trainers and rehab professionals to build a specific framework to work with during a competitive season.

Injury Risk Monitoring

Tracking baseline deviations can help biomechanics professionals and trainers recognize signs of fatigue or overload. It is important to choose the right key performance indicators (KPIs) to use for this purpose.

We suggest the following dataset for using plantar pressure mapping to monitor injury risk:

- **Peak Pressure Images:** Useful to detect abnormal pressure and load of the heel and metatarsal bones where stress fractures often occur.
- **CoP Progression:** Helps identify changes in CoP patterns that may be due to dysfunctional patterns in the lower kinetic chain and neuromuscular control.
- **Cyclogram:** Can be used as a marker of fatigue and poor movement coordination. This graph shows the repeated movements of the CoP during walking and running, reflecting the ability to maintain proper lateral symmetry and constant strides while walking and running.[3]

Return-To-Play Decisions

It's important to establish an athlete's baseline status in healthy conditions so pre- and post-injury data can be easily compared, should the need arise.

Return-to-play decisions are a huge challenge in sports medicine practice because there are so many factors to consider — not only when it comes to restoring an athlete's full physical capabilities, but also their psychological readiness. Plantar pressure data can help inform the decision on whether an athlete is physically ready to return to play.

We suggest a baseline measurement protocol based on two basic gait tasks:

GAIT TASK	DURATION	GOAL
Normal Walking	30 seconds	Establishing the first baseline
Easy Walking	30 seconds	Looking at changes with the increase in speed and stride frequency

To ensure a valid and reliable baseline profile, we suggest performing the measurement either at the very beginning of the preparation period or during a week where the intensity and volume of training is not on the high end of the spectrum; this avoids any interference coming from acute states of fatigue.

Testing Frequency

During the pre-season period, plantar pressure measurements can be used to create an individual baseline profile for each player to determine performance and movement efficiency, and to create an injury risk profile. Once a baseline profile has been established, plantar pressure measurements can be done daily (especially in pre-season camps) for monitoring both gait performance (short-term adaptations) and fatigue (acute response to training load).

<table>
<tr><th colspan="6">PRE-SEASON</th></tr>
<tr><th colspan="3">PROFILING/SCREENING</th><th colspan="3">MONITORING</th></tr>
<tr><th>Gait/Running Analyses</th><th>Performance</th><th>Injury Risk</th><th>Performance</th><th>Fatigue</th><th>Rehab</th></tr>
<tr><td colspan="2">Initial Baseline</td><td>Individual Risk Profiling</td><td>Short-Term Adaptations</td><td>Acute Response to Training Load</td><td>Effects of Potential Rehab Protocols</td></tr>
<tr><th colspan="6">DAILY</th></tr>
</table>

Plantar pressure data can be used as a real-time feedback tool in order to check the effectiveness of gait training interventions on short-term biological adaptations, such as rate of force development (RFD) and overall force application, as well as keeping fatigue accumulation under control.[4]

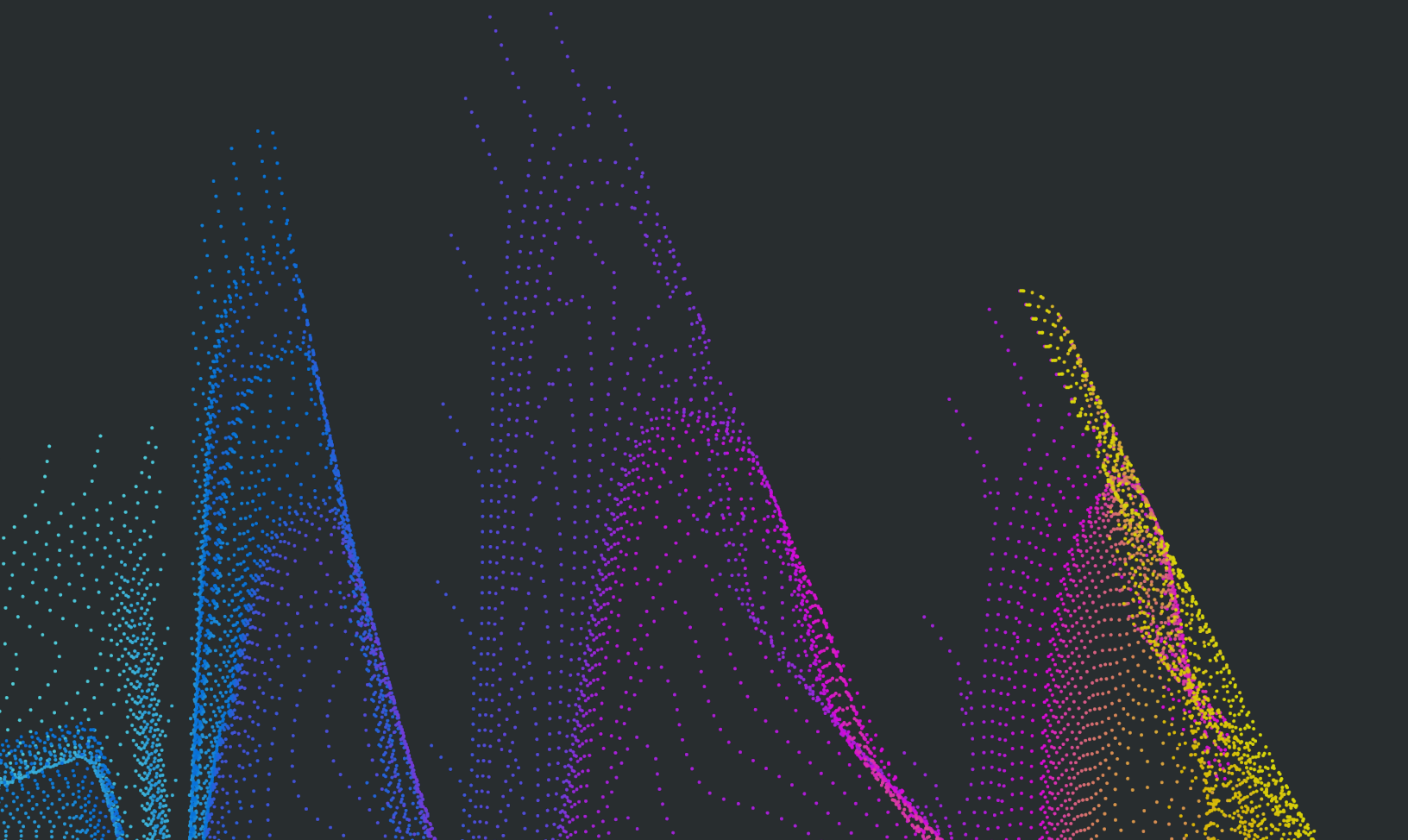
During the season, testing frequency can be reduced to a weekly basis — test twice a week to track any deviations from the baseline.

IN SEASON			
TESTING		**MONITORING**	
Gait Performance	**Injury Risk**	**Fatigue**	**Rehab**
Long-Term Adaptations and Effectiveness of Training Interventions	Compensation Strategies	Acute and Chronic	Return to Play
WEEKLY			

CHAPTER

03.

Plantar Pressure Mapping for Biofeedback



What is Biofeedback?

Biofeedback uses electronic equipment to record and provide immediate feedback on ongoing psycho-physiological processes such as skin temperature, muscle tension, heart rate or brain electrical activity.[5] In doing so, real-time biological information that would otherwise be unknown is revealed.[6]

The main goal of biofeedback is to elicit a certain degree of change within a target physiological signal, thus improving the individual's ability to develop various degrees of control.

Such control can be conscious or unconscious in nature — the unconscious control is related to a mechanism called passive association where the feedback signals are being passively associated with progress toward normalization.

Mechanisms of Biofeedback Training

The foundation of biofeedback training is based on augmented (or extrinsic) feedback which provides coaches and athletes with a level of information that's not typically available to them.

Biofeedback is delivered in two main phases:

- The practical measurement of a target biomedical variable through the use of the dedicated specific equipment
- The transmission of the feedback to the user

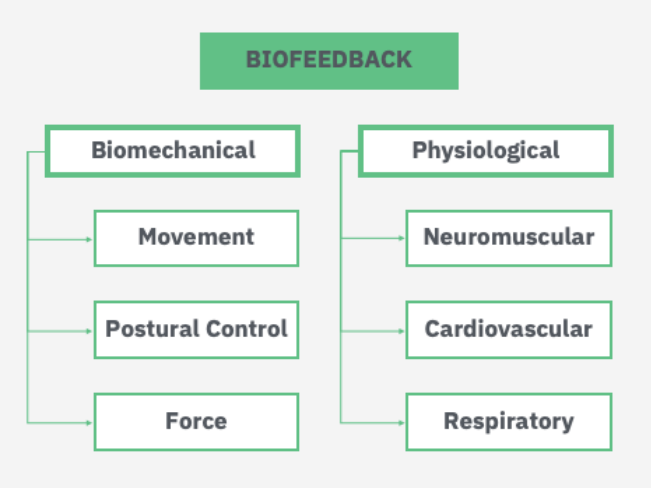


Figure 6. The categories of biofeedback used in rehabilitation (from Giggins, Persson and Caulfield, 2013)

The feedback being delivered to the user via plantar pressure mapping can either be direct or transformed feedback; the former is delivered through the visualization of raw data and curves (i.e. ECG or EMG signals) and the latter is processed feedback where the data is visualized in graphic displays and the raising and lowering scores for easier interpretation.

Biofeedback and Plantar Pressure Mapping

Using plantar pressure mapping for biofeedback can support rehabilitation and gait training.

Biomechanical biofeedback measures variables like movement, posture, and force by using equipment such as inertial sensors, force plates, electrogoniometry, pressure mats, and camera-based systems.

The feedback provided by plantar pressure measurement systems can be both direct and transformed: pressure-time and force-time curves are direct feedback and pressure maps are transformed feedback.

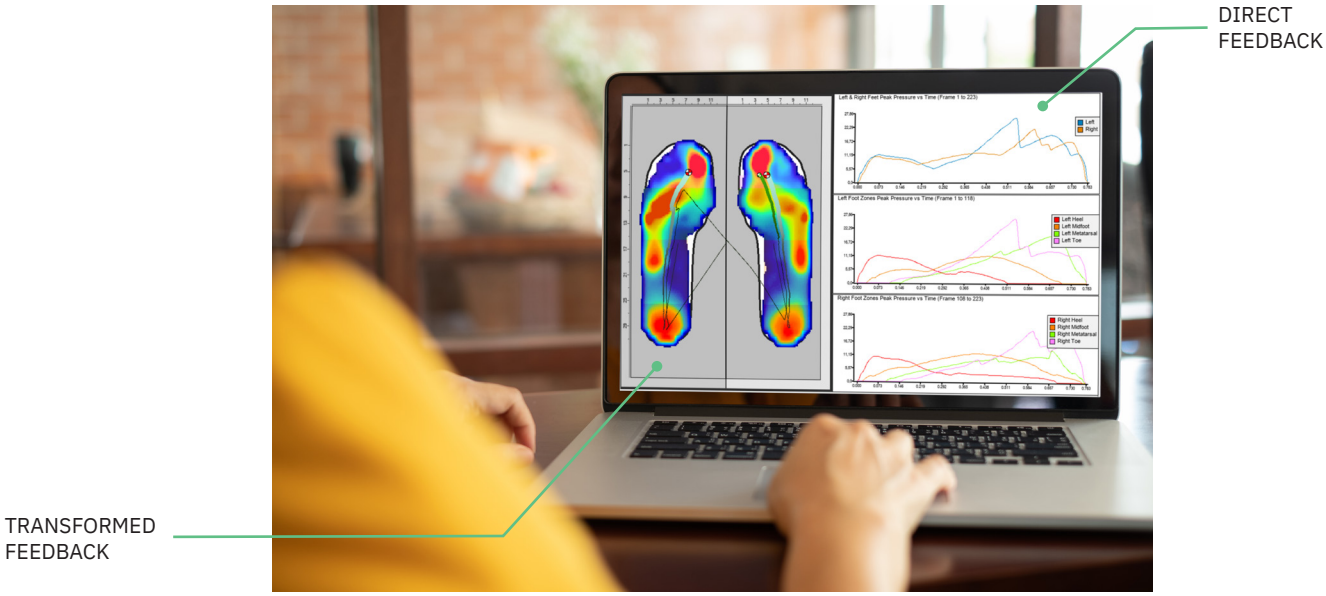


Figure 7. Transformed and direct feedback from Intelligent Insoles | Pro

For rehabilitation, biofeedback with plantar pressure mapping can help with:

- Decreasing recovery time
- Supporting return to play decisions
- Improving athlete engagement
- Increasing the efficacy of the rehabilitation program

APPLICATIONS	
POST-SURGERY REHAB	**INJURY REHAB**
Hip Knee Ankle	Ankle Sprain Hip Mobility Calf Injuries

Virtually every lower extremity injury or post-surgery process can benefit from adding plantar pressure mapping technology.

For gait training, plantar pressure biofeedback can provide athletes and coaches with real-time information that can be leveraged to improve human performance.

ATHLETE	BIOMECHANICS PROFESSIONAL
Improving and reinforcing movement skills	Improving assessment skills
Optimizing kinesthetic awareness	Improving coaching capabilities
Learning how to offload	Refining training modalities
Learning neuromuscular control	Optimizing technique

XSENSOR Plantar Pressure Measurement Systems

There are plenty of plantar pressure measurement systems available, so how can you choose which one is right for your practice? A great starting point is identifying your end goal: do you need the system to help you measure gait performance or rehabilitation, or both? If you're considering an XSENSOR product, here's an easy way to see which system matches your needs.

	Intelligent Insoles | Pro	Walkway Sensor	Stance Pad Sensor
Injury Risk Screening	✓		✓
Biomechanical Efficiency Profiling	✓	✓	
Live Biofeedback			✓
Return-to-Play	✓	✓	

Conclusion

Plantar pressure mapping can directly inform your gait assessment strategies by helping you understand how an athlete is moving and how efficient their biomechanical output is.

In the second part of this ebook series, we've covered:

- How plantar pressure mapping is beneficial in athletic gait assessments
- The importance of establishing baselines profiles, particularly when it comes to making return-to-play decisions
- What biofeedback is, and how plantar pressure mapping can help
- Which systems are best suited to certain goals

With this understanding, you can minimize the risk of injury, develop individualized training and rehabilitation programs, and improve gait performance.

For more information on XSENSOR's plantar pressure measurement systems, visit xsensor.com/human-performance

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