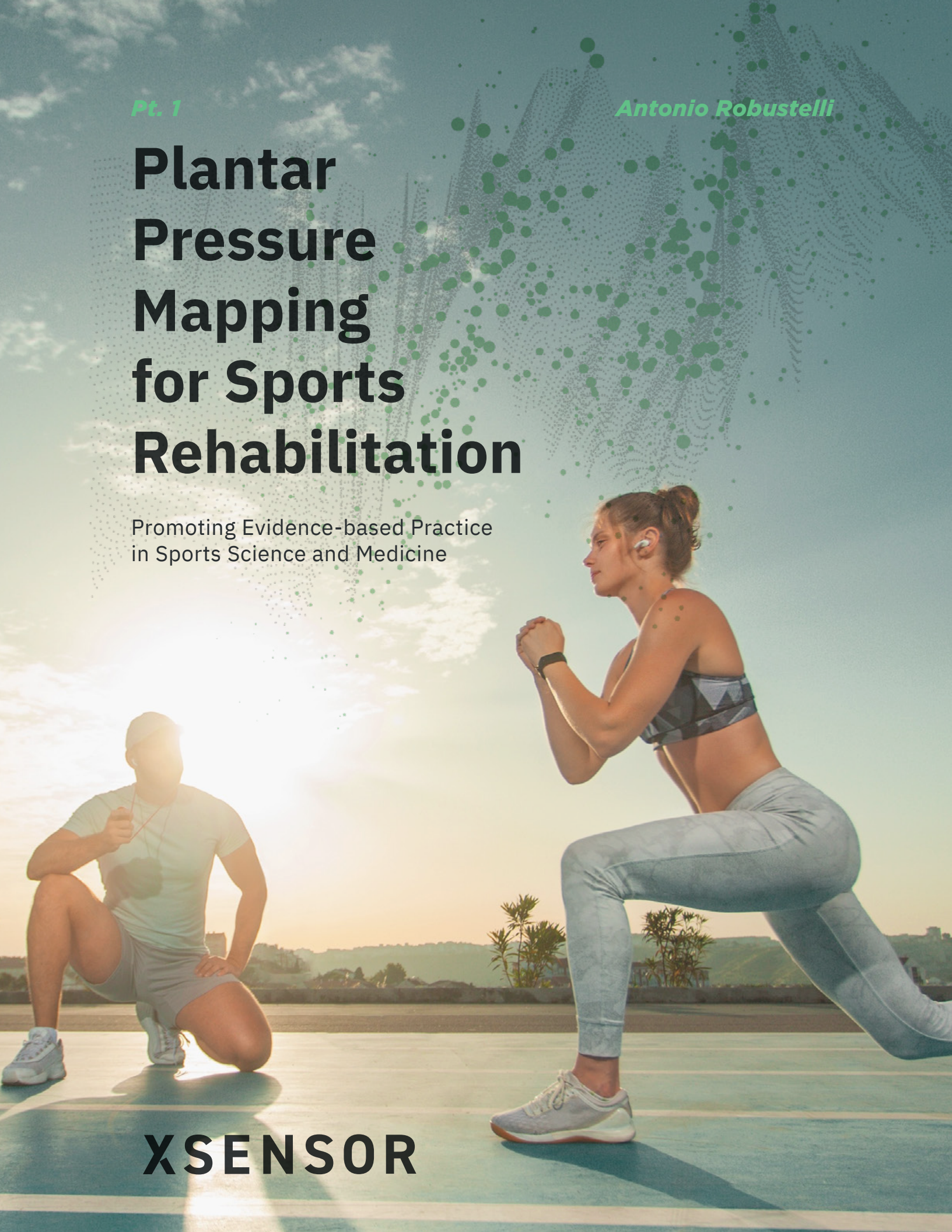
Pt. 1

Antonio Robustelli

Plantar Pressure Mapping for Sports Rehabilitation

Promoting Evidence-based Practice in Sports Science and Medicine



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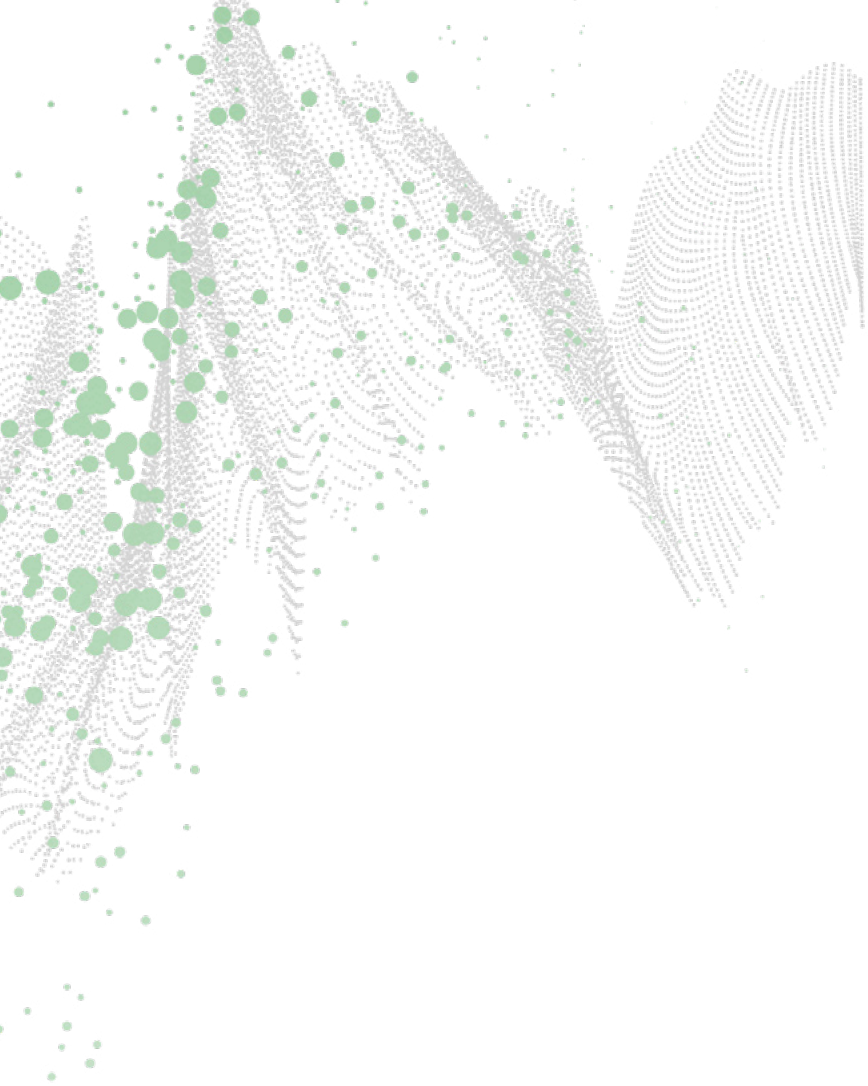

Plantar Pressure Mapping for Sports Rehabilitation

Written by Antonio Robustelli
Edited by XSENSOR Technology

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Evidence-based Practice in Sport Science and Medicine

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Mechanisms of Lower Extremities Injury

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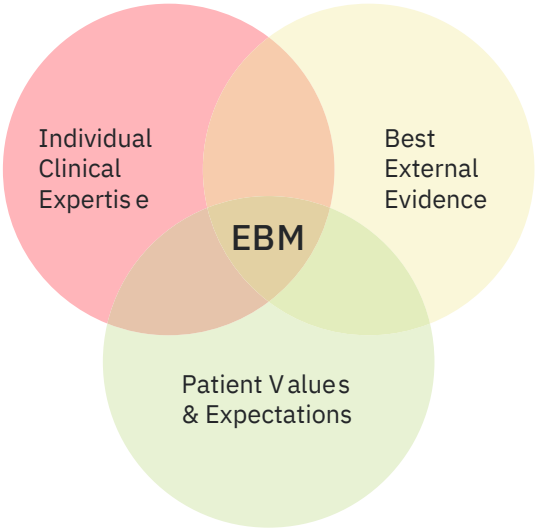
Gait Analysis and Plantar Pressure Mapping: a Basic Movement Pattern

Next in the Series:
Plantar Pressure Mapping and Gait

Fig. 1



In the field of clinical practice in sport science and medicine, the term 'Evidence-based Practice' has come to be used by professionals attempting to describe the approach of 'applying scientific findings to drive decision-making in their work'.

The first definition in scientific literature of the concept of Evidence Based Medicine (EBM) dates to 1996.

Sackett et al. defined Evidence Based Medicine as the "integration of the best research evidence with clinical expertise and patient values to make clinical decisions" (1).

Their original statement, which first introduced the concept of EBM to practitioners in the medical field, assumes that proper care and support of patients must go through a process led by the integration of Individual Clinical Expertise and External Clinical Evidence.

The strict interplay between these two elements and Patient Values and expectations is the key factor behind the concept of EBM (Fig.1).

The authors define the Individual Clinical Expertise as 'the ability and set of skills that a clinician develops over time in his daily practice', whereas the External Clinical Evidence refers to relevant research findings resulting from patient-centered clinical research.

Given the rapidly and constantly evolving nature of science and its clinical findings, it is clear that the main goal of a professional should be to keep their body of knowledge up-to-date with the latest in scientific literature.

These fundamental aspects lead to a couple of necessary considerations when trying to successfully implement an EBM approach:

i. Firstly, there is the need to establish a rigorous and systematic framework which helps in narrowing the field of research and focusing on what is really important for the advancement in patient support and care; and

ii. Secondly, it is important to avoid considering scientific literature as a sort of blueprint or strict guidelines to be used without proper critical thinking.

In fact, it has been pointed out by Steves and Hootman (2004) that "clinical decisions are not made by evidence alone; as such research evidence should never be accepted blindly. Research study results must be combined with the clinician's knowledge and experience, as well as the consideration of what is important to the patient. It is a mistake to characterize EBM as a cookbook or blueprint on how to care for patients" (2).

CHAPTER

01

Evidence-based Practice in Sport Science and Medicine

Practical Aspects of an Evidence-based Approach

Evidence-based Practice and Plantar Pressure Mapping Technology

The evidence-based approach has seen an overall increase in adoption these last few years, leading to some criticisms aimed at the effect of its implementation.

The ability to find the right balance of emphasizing external evidence AND individual expertise seems to be the key to avoid falling into the trap of turning science into ‘scientism’.

Most of the criticism seems to be aimed at the risk of the implementation of the evidence-based approach potentially “minimizing the importance of the practitioner’s experience” (3).

This risk, however, can be mitigated by using research findings to additionally inform the practitioner’s decision-making process in their daily practice.

Practical Aspects of an Evidence-based Approach

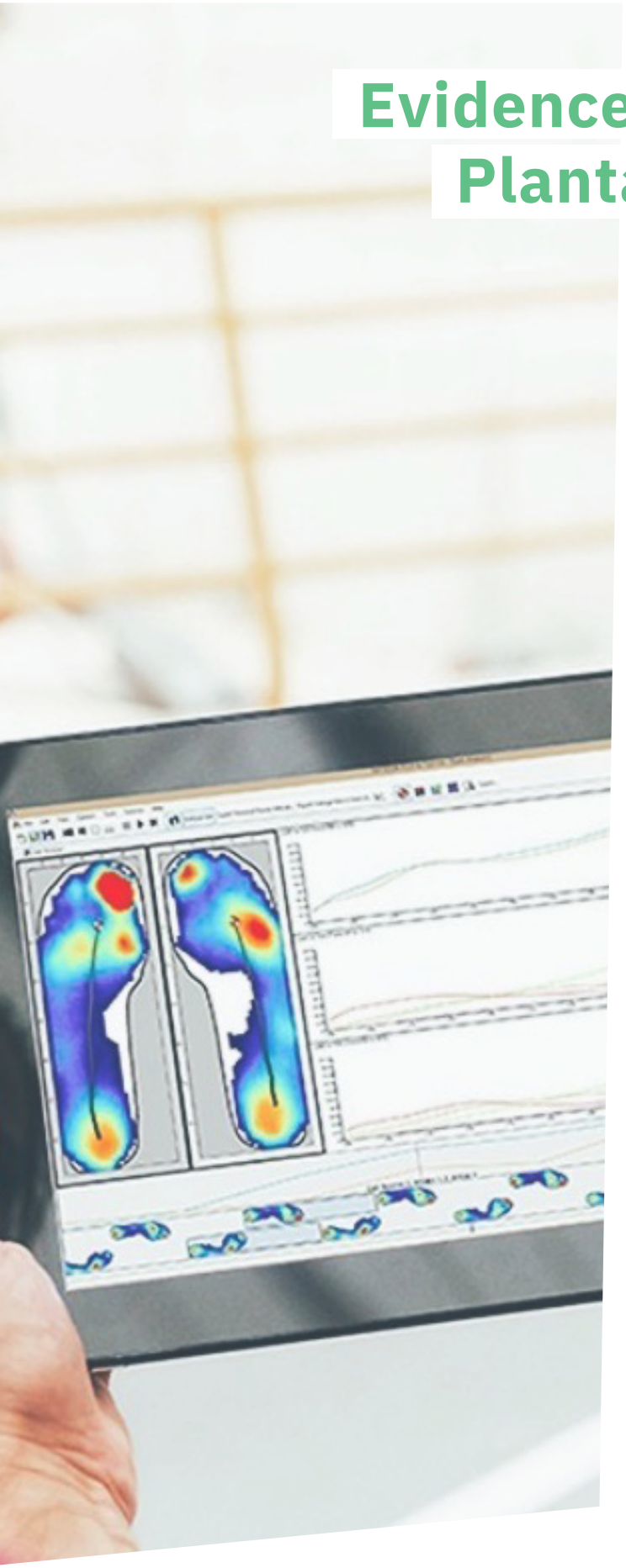
The wide range of disciplines encompassing the study and management of Human Performance is quite susceptible to false claims and misinformation. This is in part due to some agencies requiring no previous academic education to certify instructors, which leads to a considerable number of underqualified professionals practicing (3).

In this context, the evidence-based approach can be considered a methodological skill which aims to create standardization, avoid the spread of misinformation and develop highly qualified sport science and medicine professionals.

Amonette, English and Hottenbacher (2010) proposed a 5-step structural framework for evidence-based practice in exercise science consisting in the following:

1. Develop a question
2. Search fo evidence
3. Evaluate evidence
4. Incorporate evidence into practice
5. Routinely re-evaluate the evidence

The goal of such a framework is to provide practitioners with a well-defined method for EBP implementation so as to improve the credibility of their discipline and continually stay abreast of the latest in field knowledge.



Evidence-based Practice and Plantar Pressure Mapping Technology

The same evidence-based practice rules apply when it comes to the use of human performance measurement technologies such as Plantar Pressure Mapping.

The rigorous and systematic evaluation of scientific literature needs to be correlated with knowledge gained by the practitioner in order to drive best practice, which should be based on a unique blend of science, experience and intuition.

Plantar Pressure Mapping has the potential to play a fundamental role in promoting best practices in sports medicine due to the wealth of data and insight it provides for lower extremities function, something that is unique to the technology.

The ability to measure and understand what happens dynamically with the plantar surface of the foot (the only point of contact with the ground) is a powerful driver for EBP, with the evidence being the end-result of scientific research in the lab and clinical findings on the field.

The challenge for plantar pressure mapping application over the next few years will be to continue improving the practice of sports medicine and science by mirroring the advances in applied research and technology.

In the following chapters we will look at how we can implement plantar pressure measurement technology in the context of EBP.

CHAPTER

02

Mechanisms of Lower Extremities Injury

Injury Risk and Injury Prediction

Mechanism of Injury

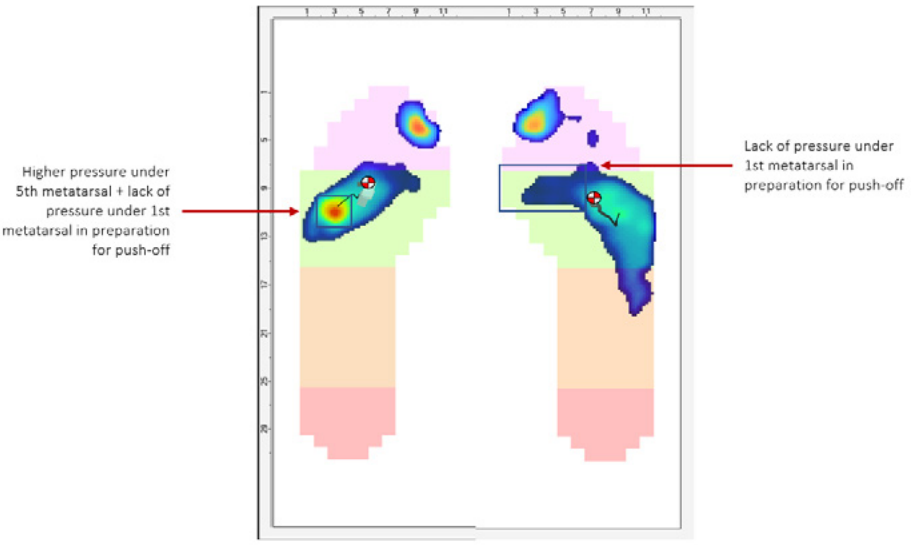
Injuries in sport occur as a result of the interplay between several mechanisms and factors which generally follow an unpredictable path due to the complex and multifactorial nature of their etiology.

Great effort has been put into the research of predicting injury risk, though results have been at times contradictory due to methodological aspects in research design.

Some authors have suggested that trying to identify risk factors using retrospective studies instead of tracking injuries with prospective studies may negatively affect accuracy and precision (4).

Fig. 2

A potential red flag for 5th metatarsal stress during high-speed running identified with Plantar Pressure Mapping



Injury Risk and Injury Prediction

From a terminological point of view, Injury Prediction refers to the analytical process used with the aim to predict the occurrence, severity, or type of injury based on the identification of Injury Risk and Risk Factors (5).

Injury Prediction is one of the key components of a sound and structured injury prevention approach, and yet represents one of the most challenging issues in sport science and medicine today (6).

The relationship between Risk Factors and Injury Occurrence is complicated due to the complex nature of human health conditions. Traditional techniques being used in sport injury research, such as logistic regression, have shown inconsistency in the identification of Risk Factors in specific categories of injury such as hamstring strain and patellar tendinopathy (6).

The tendency to use a reductionist approach to understand a complex phenomenon like Injury Occurrence has been dominant in sport injury literature. A consequence of this approach has been the reduction of the injury phenomenon to a series of small isolated phenomena and no interaction among the various factors at the base of the etiology of injuries (6).

A first step in the paradigm shift toward a more complex approach has been represented by the work of Meeuwisse *et al.* (7), who developed a model based on the assumption that injury behaves in a non-linear way and that risk factors are prone to continuous change due to adaptations to chronic exposure to primary risk factors, represents a first step towards a more complex approach.

An interesting new model for the understanding of the complex etiology of injuries, which is based on the concept of *Web of Determinants* first proposed in 1998 by Philippe and Mansi (8), has been proposed by Bittencourt *et al.* (6).

In this model the authors suggests that a *web of determinants* is resulting from the interaction of different units/variables of a complex system which in turn leads to an emerging pattern of injury/adaptation.

They propose a move toward a more complex approach to the understanding of sports injuries, from trying to find causes to identifying relations between variables which lead to the occurrence of an injury pattern.

Mechanism of Injury

The model proposed by Meeuwisse in 1998 first described the complex interaction between different Risk Factors and their respective roles in the occurrence of injury.

These factors have been categorized as internal (intrinsic) and external (extrinsic) (Fig. 2):

- *Internal Risk Factors* can be represented by age, sex, somatotype, flexibility, body composition and previous history of injury;

- *External Risk Factors* can be represented by the type of shoe, type of surface, environmental conditions, external temperature etc.

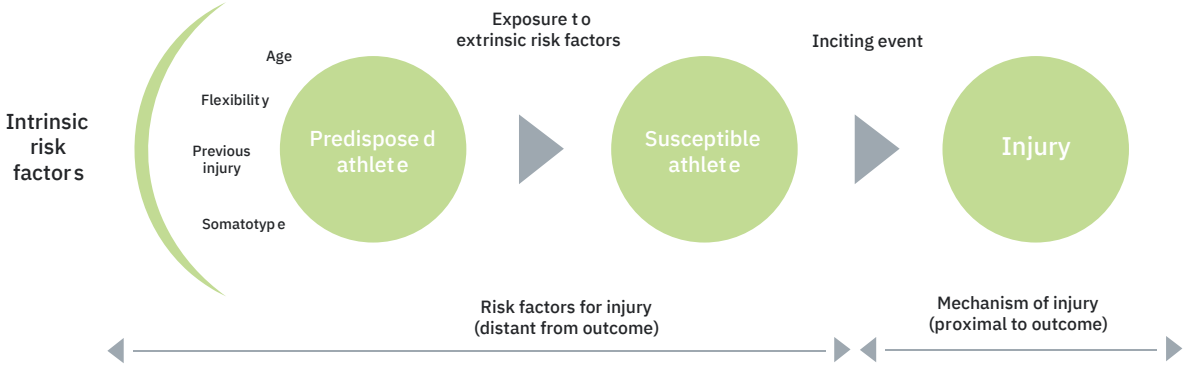


Fig. 3

The interaction between internal and external factors can make an athlete predisposed to injury even more susceptible, thus creating the conditions for the inciting event to occur, which Meeuwisse described as 'the final link in the chain that causes injury' (7).

In sport science and medicine literature it is common to use the term 'injury mechanism' to describe the inciting event and Bahr and Krosshaug (2005) suggested a classification of these mechanisms into four main groups:

i. Playing Sport Situation, the situation described from a sports specific point of view;

ii. Athlete/Opponent Behavior, a qualitative description of the athlete's action and interaction with the opponent;

iii. Whole Body Biomechanics, a description of the biomechanics of whole body;

iv. Joint/Tissue Biomechanics, a description of biomechanical characteristics of tissues.

Based on this understanding of the complex nature of injury mechanisms, the next chapter will look at Plantar Pressure Mapping technology and its ability to inform best practices in sports medicine and sports rehabilitation, as well as help in Injury Risk monitoring and Risk Factors identification.

The wealth of information obtained by plantar pressure mapping technology, paired with the unparalleled quality of recordings carried out with high sampling frequency and high resolution it's playing a crucial role in the way sports scientist and sports medicine professionals are evaluating and monitoring athlete performance in the context of injury prevention and reduction.

The application of wireless pressure insoles in sport can open a window into how the foot is functioning and handling the biomechanical output of an athlete.

CHAPTER

03

Gait Analysis and Plantar Pressure Mapping: a Basic Movement Pattern

What is Gait?

The Evaluation of Gait in Athletes

When it comes to understanding how an athlete moves his body in relation to the environment, gait represents one of the most underrated motor patterns in the sports performance industry.

The Gait Pattern can be defined as an automatized movement of the human body, which is highly individualized and deeply fixed in the CNS. Its assessment and analysis can provide sports professionals with an unparalleled amount of information on the dynamic function of the sensorimotor system (10).

What is Gait?

Gait is a complex motor task which involves an optimally sequenced, timed and coordinated movement of the limbs with the aim to propel the body's Center of Mass (CoM) forward while maintaining stability.

In simple terms, it is the fundamental pattern of locomotion of an individual, essentially the way they move.

During steady state walking the human body can be seen as an inverted pendulum (Fig. 4), which is the biomechanical model used to analyze the dynamics of balance.

To ensure optimal balance during human locomotion, the CoM should either remain within the base of support or move between two feet (when it temporarily lies outside the base of support) (11).

The inverted pendulum model provides the trajectory of the CoM and CoP as they relate to each other, relaying the understanding of the continuous tasks that must be accomplished by the central nervous system to maintain balance in a gravitational environment.

As such, analyzing individual Gait Pattern can be extremely helpful in understanding the functional status of the sensorimotor system.

In Figure 4 we can see how the CoM never passes within the base of support of either foot by moving forward along the medial aspect of each foot. During the single-support period the body acts as an inverted pendulum and the horizontal acceleration is determined by the vector that joins the CoP to the CoM. This explains the complex and challenging nature of a Gait Pattern, in that the body is never more than about 400ms away from falling, and it is the alternation between increase and decrease in CoM velocity as well as the trajectory of the swinging foot that affects the stability of the system during each single-support period (11).

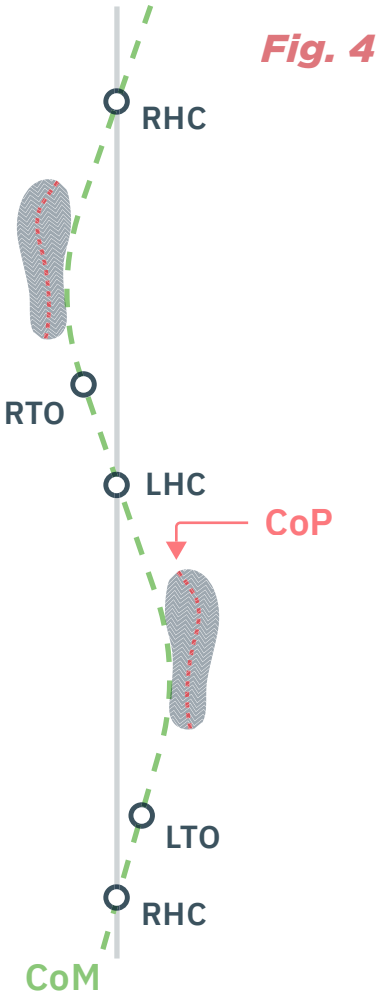


Fig. 4

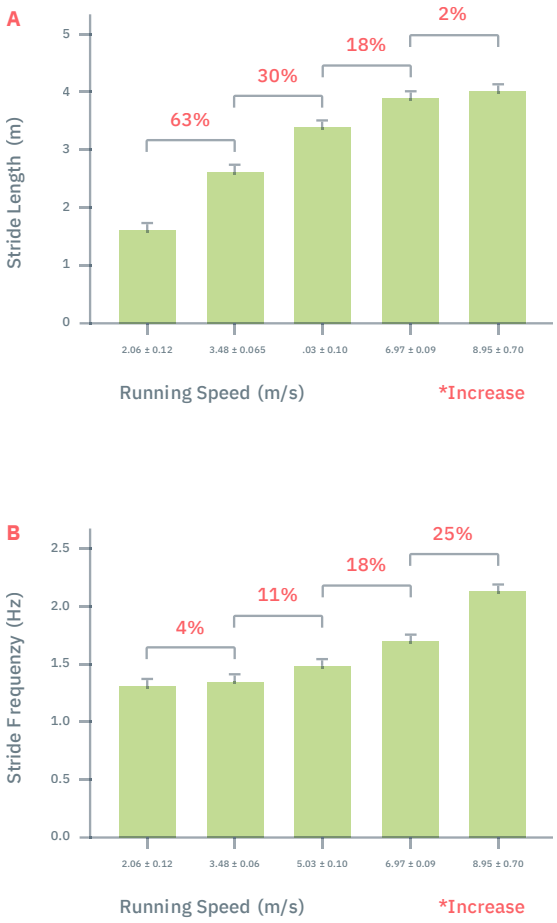
Fig. 5

Gait can be categorized as walking, jogging, running and sprinting gait depending on speed, foot strike pattern and overall body mechanics.

Transitions from a type of gait to another occurs at certain threshold of speed (12):

- ***Walking gait*** transitions to jogging gait at a threshold of 2.0 m/s
- ***Jogging gait*** transitions to running gait at a threshold between 3.5 to 7.0 m/s
- ***Running gait*** transitions to sprinting gait from 8.0 m/s upwards

With the increase in speed there is also an increase in both stride length and frequency while less time is spent in the stance phase (Fig. 5).

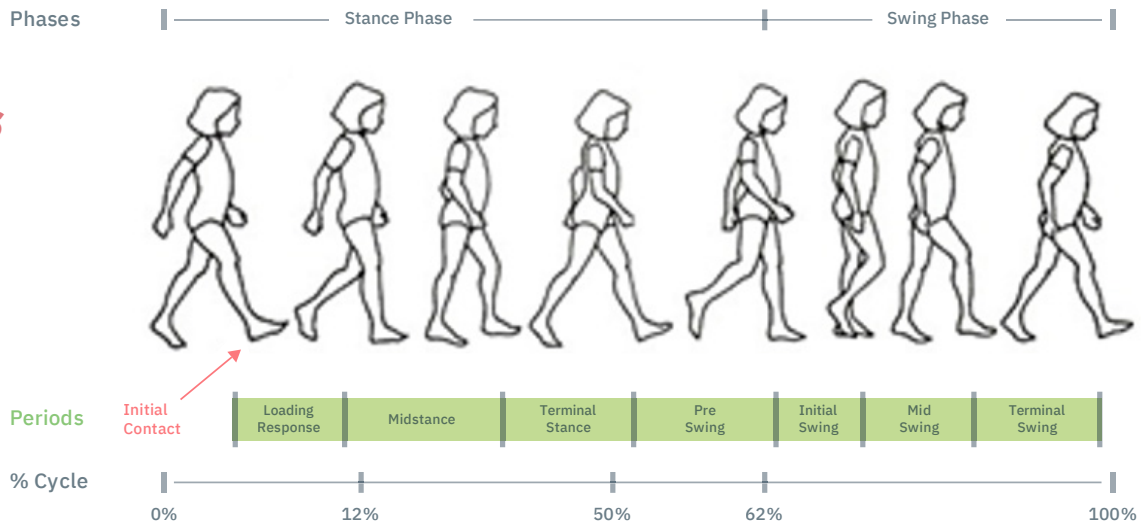


Human gait can be defined as a “complex bipedal movement with many subtasks that must be simultaneously satisfied and that are continuously changing over the stride period” (11).

A gait cycle comprises a series of events occurring from heel strike to heel strike and is divided into two phases: the Stance and the Swing.

According to Perry (13), the stance and swing phases are further divided into eight subphases (noted as ‘Periods’ in Fig. 6):

Fig. 6



The stance phase accounts for about 60% of the entire gait cycle while the remaining 40% is the swing phase.

In the Gait Cycle, the step length is the distance traveled from one heel strike to the next, the stride length is the distance from heel strike to heel strike on the ipsilateral side, and the step width is the lateral distance between the heel centers of two consecutive steps.

The Evaluation of Gait in Athletes

As covered earlier, human gait is a complex motor task and a basic movement pattern that represents an individual marker of the overall stability and dynamic function of the sensorimotor system.

The sensorimotor system is a very complex system that incorporates "all the afferent, efferent, and central integration and processing components involved in maintaining functional joint stability" (14).

As the sensorimotor system is interdependent with both, the neurological and the musculoskeletal system (10), its evaluation provides valuable insight into balance, muscle recruitment and stability of an athlete thus potentially an improved ability to recognize the risk of injury, as well as problems leading to underperformance and/ or poor recovery.

Gait analysis can be accomplished by using different techniques, methods and tools depending on whether a professional is interested in kinetics, kinematics or a blend of both types of data.

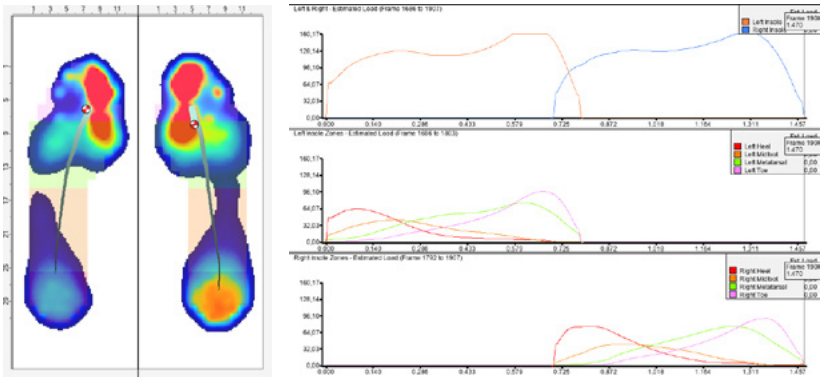


Fig. 7

An example of a gait analysis baseline test performed on an athlete

Per the example illustrated above, gait analysis performed on athletes using plantar pressure mapping insoles merits to be at the foundation of any functional assessment. Baseline profiling of an athlete's gait fulfills all the following requirements, and provides valuable insight for continued Tracking of Deviations and Injury Risk Monitoring, as well as support for a Return-to-play rehabilitation process following an injury:

i. It is a foundational movement pattern;

ii. It requires optimal stability, balance and coordination;

iii. It provides important insight into any potential compensation/ asymmetry in the body.

Lightweight and truly wireless systems like XSENSOR's Intelligent Insoles enable the evaluation of gait pattern in athletes as they allow for natural, unhindered motion of it's wearer at all times.

Being that the main goal of a modern plantar pressure system is to bring the assessment out of the lab and into the field, such an assistive system needs to work in a real-world context and scenario so as to remove limitations and allow for the athlete's performance to be at its most optimal and true to the natural skill of the sport.

Next in the series: Plantar Pressure Mapping and Gait

Plantar pressure mapping is one of the most promising technologies to recently be used in the evaluation of gait in athletes.

In part two we will have an in-depth look at how the technology can support best practices and detail its significant role in Injury Risk Monitoring, as well as in optimizing process and outcomes of Sports Rehabilitation.

Stay tuned..

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