Tekscan®

Pressure Measurement in the Gait Lab:

Why You Need It!



Introduction

The purpose of this eBook is to present you with an overview of Tekscan's measurement systems that are designed for use in a gait lab. The eBook presents examples, from published papers, on the contributions that these systems have made in helping a healthcare practitioner or researcher in the gait lab, and to better understand the underlying conditions of the patient or test subject.

The content in this eBook is presented in 6 sections:

1. Pressure Measurement
2. Tekscan Medical Pressure Measurement Systems Used in Gait Labs
3. Common Measurement Systems in the Gait Lab
4. How do Tekscan Pressure Measurement Systems Complement Other Measurement Systems in the Gait Lab?
5. How do Pressure Measurement Systems Differ from the Force Plate?
6. Examples of Studies Using Tekscan Systems

1. Pressure Measurement

Pressure measurement refers to the measurement and display of the pressures that exist between two contacting objects such as the bottom of the foot with the floor or a prosthetic interface with a stump. Pressure measurement systems have long been used by the medical community for the investigation, diagnosis, and rehabilitation of foot and gait problems. The footwear community has also used pressure measurement systems to help them design and develop footwear that addresses specific foot conditions, reduces the risk of lower limb injuries, optimizes sports performance, and increases comfort.

Pressure is one of the many parameters measured and calculated with these systems. For example, contact area, ground reaction force, and derivatives of force, such as center of force, trajectories and impulse (force-time relationship) are other measurements provided by these systems.

In addition to force and force-related measurements, the systems provide gait related timing and event parameters. To site a few parameters which are of particular interest to a gait lab, there is heel strike, mid-stance, propulsion, stance and swing, step, stride, and steps-per-minute.

A pressure measurement by itself is not enough to meet the diverse needs and challenges of a gait lab; contact area, ground reaction forces, center of force trajectories, impulse (force-time relationship), cadence, and contact times are all important measurements to a gait lab. Tekscan's Pressure Measurement Systems rise to the challenge by providing these and other key parameters related to gait, such as heel strike, mid-stance, propulsion, stance and swing, step, stride, and steps-per-minute.

Pressure Measurement & the Gait Lab

Clinicians and researchers working in a gait lab use a wide range of assessment tools to evaluate various biomechanical movements such as:

- Walking evaluations and assessments of individuals who have suffered physical and/or neurological disorders leaving them with impaired physical mobility
- Physical rehabilitation to improve balance and stability, gait training and re-training, injury and performance training of athletes
- Students conducting research as part of their curriculum in undergraduate and graduate programs
- R&D related to medical and sports oriented footwear and equipment

In summary, gait labs have as a primary mission, to measure and study gait patterns and other activities (ex: standing still), with goals to better understand and treat abnormalities and disorders. Gait analysis primarily consists of measuring and analyzing kinetic (ex: force, pressure) and kinematic (joint angle, segment velocity) parameters of joints and segments, the gait cycle, and muscular activity. Tekscan's Pressure Measurement Systems are designed to provide objective information to evaluate gait, foot function, and other biomechanical functions. These systems provide additional information beneficial to these types of evaluations. Later in the eBook, we will discuss those unique parameters provided by pressure measurement systems.

2. Tekscan Medical Pressure Measurement Systems Used in Gait Labs

Tekscan has various pressure measurement systems designed for use in the Gait lab. There are four categories for these systems: In-Shoe, Mats and Walkway, Balance Platforms, and Prosthetic Fitting.

In-shoe Pressure Measurement Systems

Brand Name: F-Scan® System

The F-Scan uses ultra thin, flexible sensors placed inside the shoe to provide detailed information about what is actually occurring inside the footwear. It captures valuable information for foot and gait analysis including timing, pressure, and force.



Thin, trimmable F-Scan in-shoe sensors provide a detailed gait analysis.

Mat and Walkway Platforms

Brand Names: MobileMat®, MatScan®, HR Mat™ and Walkway™ System

The Mat and Walkway Systems consist of thin rectangular mat sensors embedded in a very low-rise platform, which captures timing, pressure, force, and other valuable information for foot function, and gait analysis during a clinical assessment, research, and/or product development trial.

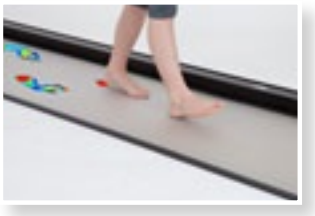


MobileMat

Balance Platform Systems

Brand Names: MobileMat®, MatScan® and HR Mat™

Integrated protocol driven software is combined with the platforms to capture weight-bearing distribution, center of force displacement, and other valuable measurements for postural stability, balance, sway, fall risk and concussion assessments during a clinical assessment, research and/or product development trial.



The Walkway is available in various sizes for versatile applications.

Prosthetic Fitting System

Brand Name: F-Socket™ System

The F-Socket uses ultra-thin, high-resolution sensors placed within the socket for detailed information about the interaction occurring inside the prosthetic socket. The sensors capture timing, pressure, force, and other valuable information for socket and gait analysis.

In summary, the Tekscan Medical Systems presented in this section are used as measurement and analysis tools for studies conducted in gait labs. Next, we'll talk about the other common types of devices found in a gait lab, which can be combined with Tekscan Systems for enhanced data.



F-Socket System

3. Common Measurement Systems in the Gait Lab

Within gait labs, there's a variety of measurement systems used to collect and analyze kinetic and kinematic data of subjects/patients in static and/or in dynamic activities pending the purpose at hand. These measurement tools can primarily be grouped into 3 categories:

1. Joint and Segment Motion Measurements
2. Ground Reaction Force and Pressure Measurements
3. Muscle Activity Measurements

Joint & Segment Motion Measurements

Motion Analysis Systems are used to obtain the magnitude and timing of individual joint and segment angles and motions. Direct measurements use electrogoniometers that are attached to the body. Indirect measurements (no contact with the body) use film or video cameras. The images obtained by the cameras are then digitized (analytically processed) to obtain the positions and orientations of the segments and the joints.

In motion analysis of joints and segments, the addition of measurements from pressure measurement systems is valuable. Combined, these provide a more complete perspective on the nature of the event under investigation, such as with foot function, gait, posture, balance, and sway. For example, during gait, a delayed heel lift combined with early forefoot contact, are associated with reduced motion about the ankle. Clinically, reduced motion of the ankle joint is also referred to as equinus. Together, joint and segment motion measurements with plantar pressure measurements provide a greater insight into the nature of the event under investigation.

Ground Reaction Force & Pressure Measurement

Force plates, in-shoe, and floor mat pressure measurement systems are the most common types of systems in this category. The force plate is used to obtain the three-dimensional magnitude inferior-superior (vertical), anterior-posterior (back-front), and medial-lateral (side-to-side) ground reaction forces experienced on the plantar surface of the foot (or footwear) of the weight-bearing limb. Force plates usually consist of a solid top plate on top of a set of three-orthogonal piezoelectric sensors (or strain gauge transducers) located under the corners of the top plate. These provide an electric output proportional to the force applied on top of the solid plate. In addition to force, force plates provide location for the center of force (CoF) on the top plate.

The in-shoe and floor mat pressure mapping sensors (such as Tekscan systems) are matrix-based, composed of a varied number of cells (also called sensels) within a sensor. These are used to obtain total and localized segmented regional vertical ground reaction force, CoF location and trajectory exerted on the plantar foot and footwear, along with other measurements; such as pressure and contact area of the weight-bearing plantar foot. These systems use different kinds of thin force sensors, such as resistive (Tekscan), and other systems use capacitive strain gauges, conductive rubber, or piezoelectric materials. Due to the nature and need of very thin sensors, the measured forces are restricted to the vertical component.

In ground reaction force analysis with force plates, the measurements from pressure measurement systems are a valuable addition. These combined provide a more complete perspective on the nature of the event under investigation, such as during foot function, gait, posture, balance, and sway. For example, while standing static (balance and sway analysis), an increase in pressure on the left heel combined with a left and rear shift of the foot's center of force location are associated with a twist in the trunk (spine) and/or a shorter lower limb. Clinically, the presence of a twist in the spine is also referred to as a scoliosis, and the presence of a shorter limb is referred to as leg length difference (LLD). Together, the ground reaction force measurements with plantar pressure measurements provide a greater insight into the nature of the event under investigation.

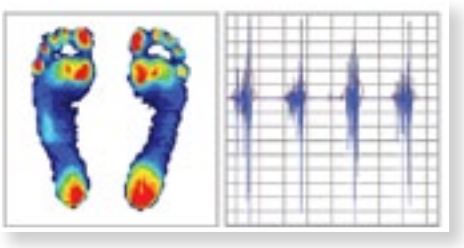
Muscle Activity Measurements

Electromyography (EMG) Systems are used to obtain the electrical (neural) activity of a contracting muscle. Specifically, timing of muscle activation and relative intensity of muscle function are measured. There are three different kinds of common electrodes:

1. Surface
2. Fine-wire
3. Needle

Surface electrodes are positioned on the skin over the muscle belly. Fine-wire and needle electrodes are inserted through the skin and within the muscle. Surface electrodes provide the broadest degree and detail of muscle activity, while the needle electrode provides the highest degree and most specific detail of activity.

In EMG analysis of muscles, the addition of measurements from pressure measurement systems is valuable. This helps to provide a more complete perspective on the nature of the event under investigation, such as with muscle activity during foot function, gait, posture, balance, and sway. For example, during gait, weak activity and weakness of the posterior tibialis (PT) muscle can occur. This can be attributed to a combination of the following three things: 1. Increased pressure in the medial arch area, 2. Medial progression of the plantar foot center of force trajectory, and 3. High pressures at the first metatarsal head and hallux (big toe). Clinically, the presence of a weak PT muscle is also referred to as posterior tendon dysfunction (PTTD). Together, the EMG measurements with plantar pressure measurements provide a greater insight into the nature of the event under investigation or study.



Evaluating plantar pressure and EMG data together provides a complete picture.

4. How do Tekscan Pressure Measurement Systems Complement other Measurement Systems in the Gait Lab?

The Tekscan Pressure Measurement Systems have complementary features to the other systems used in the gait labs. These features help ease and facilitate data collection when two or more systems are used, and simplify data processing and analysis with two or more databases. Specifically, the following three complementary features are of particular interest to users of multiple systems:

1. Simultaneous triggering of the systems for recording
2. Frame or time synchronization between the systems
3. Portability of the Tekscan systems, allowing for use in different areas of the gait lab, or in other labs

Triggering – Start/Stop Data Collection

Triggering, or starting a recording, can be done via several means, such as pushing on a physical button, or flipping a switch on a system unit, or mouse-clicking on a button-icon in the system's software. The "simultaneous" triggering of two or more systems can be initiated via a cable connected between the systems, or via external units connected to the systems. The trigger signal can be transmitted in tethered (cable) mode, or in wireless mode.

Tekscan's Wireless Trigger Transmitter and Trigger Receiver units and the software are designed to support the transmission of a variety of signals for simultaneously triggering 2 or more systems. Note that the system sending the signal is referred to as the master, while the system receiving the signal is referred to as the slave.

Practical Example: Wireless Triggering

Illustrated to the right is an example of a wireless set-up simultaneously triggering an EMG System (master) and the Tekscan F-Scan Wireless/Datalogger System (slave). A Tekscan Trigger Transmitter (TT-1) unit is connected to the EMG console (on the left) and a Tekscan Trigger Receiver (TR-1) unit is connected to the Wireless/Datalogger unit of the F-Scan System (on the right).



Wireless Configuration

When the recording is initiated via the EMG System (master), a signal from the EMG console is sent to the TT-1 unit, which then transmits a wireless single to the TR-1 unit triggering the recording of the F-Scan Wireless/Datalogger System (slave).

Practical Example: Tethered Triggering

Illustrated to the right is an example of a tethered set-up simultaneously triggering the Tekscan MatScan Floor Mat (on the left) and an External System (not shown). Specifically, a Tekscan USB-6008 unit is connected to computer laptop running the MatScan System.



Tethered Configuration

When the recording is initiated via the MatScan (master) software on the laptop, a signal is sent to the USB-6008 unit, which then transmits a single triggering the recording of the other external system (slave).

Vice-versa, when the recording is initiated via the other system or external device (master), a signal is sent to the USB-6008 unit, which transmits a single to the laptop triggering the recording of the MatScan System (slave).

Synchronization – Collect Synchronized Data with Various Systems

System users are interested in databases where the sample rates (frames recorded per second) in the databases are synchronized. Synchronization of frames between systems can be one-to-one (1:1) sequence (1 frame of master per 1 frame of slave), or a variable sample rate such as with a one-to-ten (1:10).

Practical Example: Wireless Triggering

While walking a patient loses balance at 2.7 seconds from the start of the recording, and this event occurs at the second heel strike. In the recording of a Tekscan System (master) at 100 Hz, this loss of balance at the second heel strike will occur at frame 270 (100 frames/second * 2.7 seconds). In the recording of a Motion Analysis System (slave) at 1000 Hz, this loss of balance at the second heel strike will also occur at 2.7 seconds from start of the recording; however, this event will occur at frame 2700 (1000 frames/second * 2.7 seconds).

In the above situation, simultaneous triggering of 2 or more systems allows the systems to start recording at the same time. With synchronized frame rates between the systems at 1:10, there is ease with identifying occurrences of respective events in the different databases.

Frame Triggering

The Tekscan Pressure Measurement Systems also offer the option of setting a 1:1 sequence between the systems. For example, the master and the slave are both set to record at 100 Hz.

In reverse, frame trigger also allows a pulse signal from another system (master) to be received by the Tekscan System (slave), whereby, each time the Tekscan System receives a pulse signal from the external system, a frame of data is recorded by the Tekscan System. In this situation, both the Tekscan System and the other system have the same sample rate.

Note: the maximum synchronized sample rate is limited by the system with the lowest maximum sample rate.

Portability – Transport your Tekscan System for Use in Various Locations

Tekscan Systems are light-weight and durable making them very easy to transport and set-up in different locations within the gait lab. This makes them easy to transport and set up in different locations. Examples are illustrated at right.

In summary, the Tekscan Pressure Measurement Systems complement other systems used in gait labs. They help ease and facilitate data collection when two or more systems are used. They also simplify the data processing and analysis when multiple databases are used. Of particular interest, the Tekscan Systems and the force plate also provide similar and diverse measurements.



The F-Scan & Prosthetic Fitting systems fit in a rigid and light-weight briefcase-size carrying case.



The MobileMat platform has a carrying handle for ease of transport.

5. How Do Pressure Measurement Systems Differ from the Force Plate?

Tekscan Systems such as the In-Shoe, the Mats and the Balance Platforms have similar use as with a Force Plate. However, there are some differences with the measurements obtained with the Tekscan Systems. Specifically, there are differences in

- Information distinctiveness
- Foot segmentation capability
- Ease of use

How is the Information unique?

The force plate measures the total force applied on the top plate, where the measurement area is the full area of the top plate. Only one vertical force measurement is provided. By contrast, the measurement area of the In-Shoe, Mats, and Balance Platform sensors consist of multiple measurement areas, called sensels. These sensel elements are arranged in a matrix (row-column) configuration. For example, the F-Scan In-Shoe 3000 sensor has 960 sensels (3.9 cells/cm^2), while the rectangular MobileMat 7101 Sensor has 8,448 sensels in a matrix of 88 rows by 96 columns (3.9 cells/cm^2).

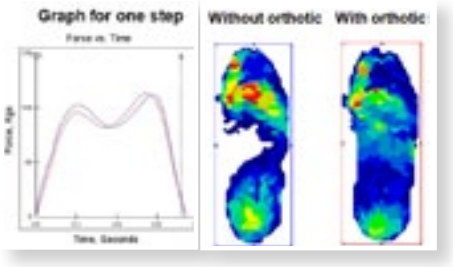
The systems provide a force measurement for each of the individual loaded sensels of the sensor. Due to the matrix configuration of a sensor, the systems provide a force measurement for each of the individual loaded sensels. This unique feature provides for additional measurements, such as pressure and contact area. Measurements such as pressure and peak pressures are calculated based on the area and forces applied to the sensels. Force contact area (pressure) on the plantar foot or outer sole of the footwear can be obtained.

Ability to segment the foot

Tekscan Systems provide force measurements (among others) for specific areas or regions of the plantar foot or outer sole of the footwear. This allows for segmenting the foot (referred to as boxing, or masking) into regions of interest, such as the heel, midfoot, forefoot, metatarsal heads, toes, etc.), and measuring the force (among others) in the respective areas of interest.

Practical Example

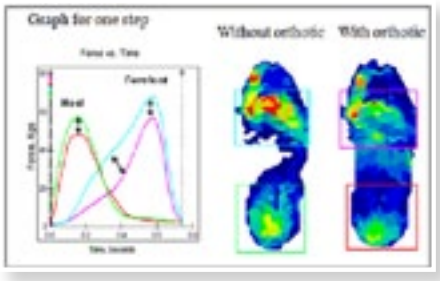
Illustrated to the right is a representation of two in-shoe pressure profiles. They represent total vertical ground reaction forces exerted on the plantar foot during stance for conditions with and without plantar foot orthotics. Note the similarity between the two curves.



F-Scan Peak Pressure Profile and Force vs Time Graph

Illustrated at right are the same two conditions as in the previous image. However, the graph displays the vertical ground reaction forces exerted on the plantar foot for the segmented heel and the segmented metatarsal regions. In contrast to the similar curve patterns for the total foot, note the differences between the two heel curves, and between the two metatarsal curves, for conditions with and without orthotics.

The examples above illustrate and confirm the importance for segmenting the foot. Analysis and interpretation of foot function based solely on the total vertical ground reaction force of the total foot can be misleading, with misinterpretation on the measurement.



F-Scan Software Display with Foot Segmentation

Ease of use

Tekscan's In-Shoe, Mats, and the Balance Platforms consist of sensors, software, and hardware. The systems are easy to use, with no need to have a technical background. The software installs automatically on the computer (desktop or laptop), while the hardware connections between the sensors and the computers are labeled respectively. Calibration of the sensors can be done by the user and requires only a subject. Recording of events, saving the data, and displaying the data in graphic and tabular formats are as easy as the click of a mouse. Data can be exported into ASCII (American Standard Code for Information Interchange) comma separated value (*.csv) and MATLAB (*.mat) file formats. The ability to export data in standard formats facilitates post-processing data for specific desired needs, and enhanced analysis, such as is used with statistics.

While Tekscan's Pressure Measurement Systems are similar in use to a force plate, they provide additional information not available with the force plate. These systems differ from the force plate with unique information, ability to segment the foot into regions of specific interest, and ease of use. Set-up, data recording, data display, and information export are a few ways in which Tekscan systems go beyond a traditional force plate.

6. Examples of Studies Using Tekscan Systems

This next section summarizes published papers highlighting application-specific uses for Tekscan systems. The following six applications are presented in this section:

1. Fall Risk Evaluations
2. Gait Analysis for Stroke Patients
3. Pediatrics
4. Footwear
5. Synchronization Capabilities
6. Physical Therapy

Fall Risk Evaluations

Do you treat patients at risk for falling?

With an increasing aging population, fall risk evaluations have become even more important. Physicians and researchers are challenged with identifying patients at risk for falling, often times through evaluating asymmetries and balance issues. Once they have determined the risk, they must develop a rehabilitation or treatment plan. How can you be sure of the effectiveness of rehabilitation or balance training? The following examples of research articles show how Tekscan's technology can aide you in fall risk assessments and evaluations in your gait lab or hospital.



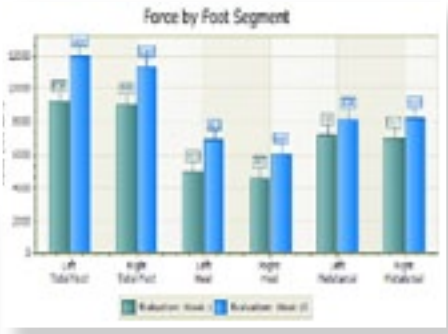
F-Scan

The Effect of Obstacle Gait Training on the Plantar Pressure and Contact Time of Elderly Women

In Kim and Hwangbo [1], the authors share the objective of their research, "The purpose of this study was to analyze whether gait training using an obstacle induces a decrease in the risk of falls through an improvement in the deterioration in elderly foot function by examining plantar pressure and contact time."

The authors comment on using foot pressure data:

"Methods using foot pressure are most widely used when examining such changes in mechanism or functional decline of foot. Not only COG pathway but also movements that control equilibrium can be identified by measuring plantar pressure against ground and center of pressure (COP) with these highly reliable methods."



Auto-generated reports display easy to read contact time graphs.

Note: Chart is not data from the research article.

The results show that foot contact time did not decrease right before crossing the obstacle but decreased right after crossing the obstacle ($p < 0.05$). Foot pressure moved from the end of the frontal foot to the midfoot (MF) and heel (HL) right before crossing the obstacle ($p < 0.05$). Foot pressure increased in lesser toe (LT) right after crossing the obstacle ($p < 0.05$).

The authors conclude from their results; "The obstacle gait training may be helpful to the elderly who would either fear for or limit outdoor activities due to the risk of falls based on the result of this study."

Gait Analysis for Stroke Patients

What effects does a stroke have on gait?

A stroke can cause various types of neurological impairments, often affecting a patients' gait. In his 2014 research, Yang et al. quotes Bohannon et al. [2] "the restoration of walking is the goal most often stated by post-stroke patients and identified as one of the most important rehabilitation goals in the stroke patients." The following articles are demonstrate examples where Tekscan Systems were used to evaluate the biomechanical effects of a stroke.

Plantar Pressure Distribution During Robotic-Assisted Gait in Post-stroke Hemiplegic Patients

In Yang et al. [3] the authors state the purpose, "We conducted this study to investigate the ankle function and gait symmetry during the robotic-assisted walking, which induces the normal physiological hip and knee motion. We compared the robotic-assisted walking with the unassisted walking on the same bodyweight supported treadmill in hemiplegic stroke patients."

System Used: F-Scan System

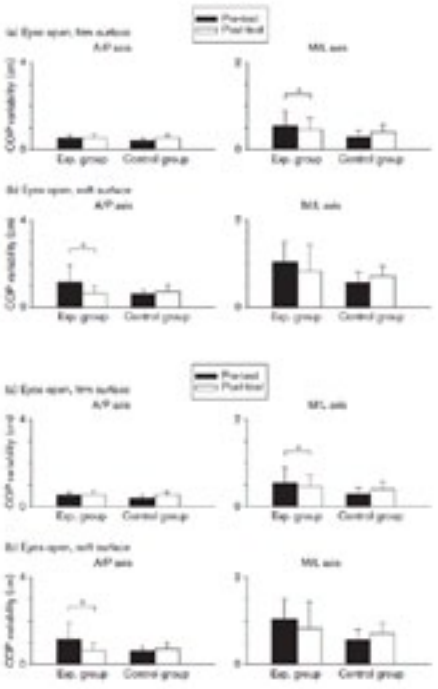
From the measurements obtained with the F-Scan System, the authors comment, "In robotic-assisted walking, the asymmetric index of contact area, stance time, and swing time between the two lower limbs were significantly improved as compared with unassisted walking ($p<0.05$). Those of contact pressure and trajectory length did not show a statistically significant difference."

Yang et al. conclude from their results, "The robotic-assisted walking may be helpful in improving the gait stability and symmetry, but not the physiologic ankle rocker function."

Table 4. Asymmetric index of robotic-assisted walking condition and unassisted walking condition

Parameter	Robotic assisted	Unassisted
Stance time	0.13±0.50*	−0.57±1.45
Swing time	−0.57±1.45*	0.40±0.83
Contact area	−5.84±27.74*	−25.21±20.35
Contact pressure	−36.54±66.52	−43.27±46.59
AP trajectory	−30.29±41.40	−58.98±52.78
ML trajectory	−8.78±41.15	−8.51±51.55
Total trajectory	−30.48±40.94	−55.79±49.25

F-Scan software automatically calculates a number of gait parameters, including stance time and swing time [3].*



Results from the different testing conditions. [5].*

Balance Training Following Stroke: Effects of Task-oriented Exercises with and without Altered Sensory Input

In Bayouk et al. [4] the authors state: "… the main objective of this study was to compare the effects of a task-oriented exercise program with and without altered sensory input on postural stability in two groups of hemiparetic subjects secondary to stroke. A second objective was to establish the feasibility of multisensory training in older adults with stroke."

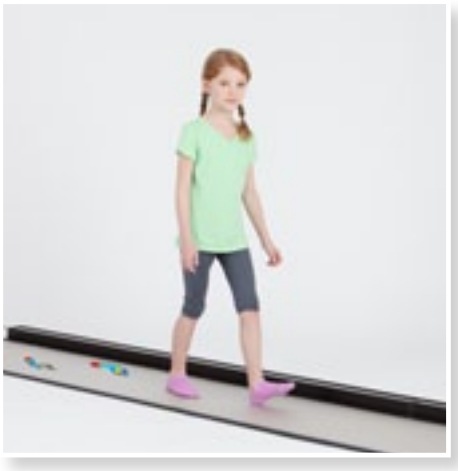
From the measurements obtained with the MatScan System, the authors comment: "Results showed significant improvements ($P < 0.05$) in COP displacement under sensory conditions (1) and (2) for the experimental group only, and limited changes for the sit-to-stand in both groups after training. Significant improvements ($P < 0.05$) were also found in both groups for the walking test."

System Used: MatScan System

The authors conclude, "Our results showed that a task-oriented exercise program assisted by sensory manipulation was feasible and more effective for the improvement of the standing balance of hemiparetic subjects secondary to stroke than a conventional task-oriented program. The significant improvements in mediolateral sway when performing a standing stance with eyes open on a firm surface further suggest an improvement in the sensorimotor integration following the multisensory program."

Pediatrics

When evaluating effects of surgery or other pathologies, in addition to objective and accurate information, reproducibility, or receiving consistent results, is another important consideration, especially when working with children. When studying the pediatric population, a higher resolution sensor is ideal to support visualization of the effect of small bones and other components of the foot. The following articles are examples of Tekscan technology used to evaluate the pediatric population.



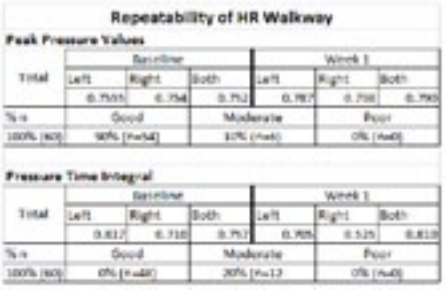
HR Walkway

Repeatability and reproducibility of the Tekscan HR Walkway System

Coda et al. [5] explain their objective for the study, "At present reliability studies with regards to recording children's gait especially using the HR Walkway has not been completed. The aim of this study is to test the repeatability and reproducibility HR Walkway in the gait of healthy children."

System Used: HR Walkway

Coda et al. comments on the barefoot pressure analysis systems, "One of the advantages of the barefoot analysis system is that the pressure sensors are always positioned parallel to the supporting surface to provide a "true" vertical force measurements."



Repeatability of HR Walkway

Peak Pressure Values

	Baseline			Week 1		
Total	Left	Right	Both	Left	Right	Both
	0.7555	0.754	0.752	0.787	0.759	0.790

% n	Good	Moderate	Poor
100% (60)	90% (n=54)	10% (n=6)	0% (n=0)

Pressure Time Integral

	Baseline			Week 1		
Total	Left	Right	Both	Left	Right	Both
	0.817	0.710	0.752	0.785	0.525	0.810

% n	Good	Moderate	Poor
100% (60)	6% (n=40)	20% (n=12)	0% (n=0)

Total values for the repeatability results [5]. The full results which include the breakdown of repeatability by anatomical area are available in the full article.*

"Compared to other barefoot analysis systems, the HR Walkway not only is able to provide high resolution recordings but also allows multiple steps recordings. This option is particularly useful when dealing with young children because in some instances up to 4 or 5 steps were recorded at the same time, which helped avoiding targeting errors during gait."

The authors concluded from the results of their study, "…the HR Walkway appears to be a repeatable and reproducible system for recording barefoot plantar foot measurements and gait in children and adolescent for research and clinical practice."

The Contralateral Foot in Children with Unilateral Clubfoot, is the Unaffected Side Normal?

Cooper et al. [6] share their objective for the study, "the purpose of this study was to evaluate whether the unaffected foot is indeed normal or if there are differences in the pedobarographic parameters of the unaffected foot compared to healthy normal controls (normal being defined as children with typical development). Specifically we compared the percentage of stance at initiation of force, the percentage of stance at maximum force, the percentage of stance at termination of force, the maximum percentage force and the average force/time integral between a group of normal age matched controls and the unaffected foot in patients with unilateral clubfoot."

System Used: HR Mat

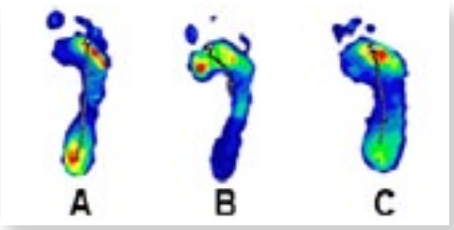
The authors use prior studies to compare pressure measurement mats to alternative methods for evaluating club foot, "These investigations can be limited since they only provide a static and possibly subjective assessment of the foot, therefore pedobarography and gait analysis have been suggested as a method of objectively assessing the dynamic function of the foot."

From the measurements obtained with the HR Mat System, the authors comment; "Significant differences were identified between the unaffected side and normal controls for the pressure distribution, order of initial contact and foot contact time. These differences evolved and changed with age. The pedobarographic measurements of patients with clubfoot are not normal for the unaffected foot. As such the unaffected foot should not be referred to as normal, nor should it be used as a control."

A Comparison Between Surgical Management and the Ponseti Technique

In Salazar-Torres et al. [7] the authors state, "The objective of this study was to determine any differences in pedobarographic outcomes between children with CTEV treated with the Ponseti technique and those who were managed with a more traditional orthopaedic approach. A comparison of these two groups with a typically developed cohort was also undertaken."

System Used: HR Mat



Pressure profiles generated from the HR Mat software (FootMat). This software, automatically calculates the Center of Force Trajectory. [7]*

The author says of the method used for the study, "Plantar pressure analysis is an objective outcome measurement of the dynamic loading of the foot, which can be used along with other clinical and radiological outcomes to provide complementary evidence on the biomechanics and structure of the foot in children with CTEV."

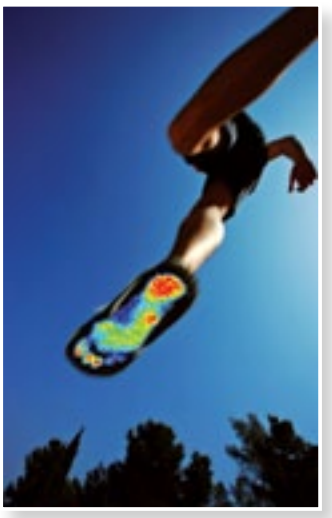
From the measurements obtained with the HR Mat System, the authors comment: "Overall, the findings suggested that while both CTEV groups experienced less pressure under the heels, greater pressure was experienced under the lateral border of the mid-foot in children managed by the Ponseti technique. The latter suggests a certain degree of under-correction for children that underwent this procedure. Conversely, increased force parameters at the medial midfoot in the surgical group suggest some degree of overcorrection. For both CTEV groups there was also a failure of transference of pressure to the hallux (medial fore-foot) at push-off and this can most likely be attributed to weakness in the plantar flexor musculature and residual equinus deformity."

Salazar-Torres et al. conclude, "the pedobarographic parameters of patients with clubfoot are not normal for the unaffected foot. As such, the unaffected foot should not be referred to as normal, nor should be used as a control."

Footwear

How does footwear affect biomechanics and gait?

Footwear trends are constantly changing. Experts are continually evaluating the effects of minimal versus maximalist running shoes, toning shoes, high heels, or another new footwear trend. How can you determine the effects of different types of footwear on biomechanics? In-shoe pressure analysis systems provide detailed information about what is actually occurring inside the shoe. Pressure measurement mats provide objective information on balance, sway, foot function, and even gait. Regardless of whether you use an in-shoe pressure analysis system or a pressure mat, it will provide data you need to determine the effect of footwear on gait and function. The following research articles evaluate the effects of various types of footwear using Tekscan systems.



In-shoe pressure analysis systems provide detailed information about the interaction between the foot and the shoe.

The Effects of Shoe Architecture on Heel Impact Forces During Gait

Lawson et al. [8] state, "The main objective of this study is to illustrate the effects that differing shoe architectures have on the impact forces observed in the heel during gait."

System Used: F-Scan System

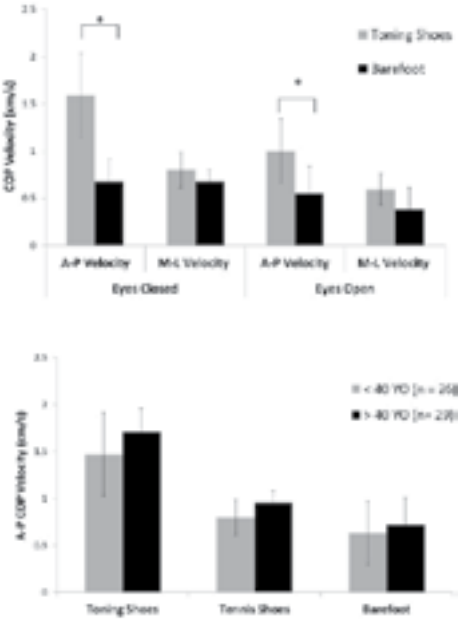
The authors' comment on the measurements from the F-Scan System, "The results from our statistical analyses indicate that there existed a significant reduction in peak forces from flexible shoes to stability shoes across all subjects for both companies ($p<0.01$), with the exception of one subject that exhibited a significant increase in peak forces from flexible shoes to stability shoes for company B (*Table 1*). The peak force results from the barefoot trials demonstrated no statistically significant trends across the subjects with respect to either company or shoe type. From this preliminary study, we were able to observe a significant difference between stability shoes and flexible shoes."

The Effects of Toning Shoes on the Postural Stability of Women

In Farley et al. [9] the authors state, "The goal of this study is to determine the effects of toning shoes on the postural stability of women."

System Used: MatScan with Sway Analysis Module (SAM)

From the measurements obtained with the MatScan System, the authors comment on the results, "In this study stability was defined by measurements of the A-P and M-L displacements, as well as the velocity of the sway in each of these directions. This study provides evidence that toning shoes affect the balance of the women who wear them, regardless of age. However, researchers also observed that toning shoes might have a greater influence on the balance and stability of older women. The manufacturers of the toning shoes equate the decreased stability of customers as an opportunity for the customers to improve muscle tone as they work towards improving their balance. However, the increased instability of older women may be problematic as extreme instability may lead to falls and injuries in an older population."



The graphs above display COP displacement for toning shoes, barefoot and tennis shoes. [9]*

Synchronization Capabilities

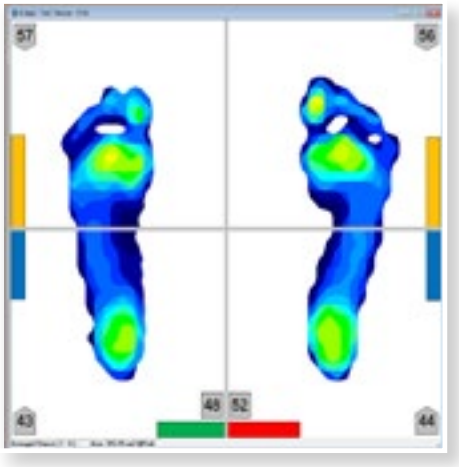
As clinicians and researchers in a gait lab evaluating human movement, the ability to relate and analyze various types of data is very important. Seeing more than one type of data allows you get a full picture of the patient or subject. With Tekscan technology, you have the ability to synchronize with various types of measurement devices. Earlier in the eBook, we discussed the variety of devices with which our technology can synchronize. The following example demonstrates the synchronization of plantar pressure data from a HR Mat and a motion capture.

A New Method for Synchronization of Motion Capture and Plantar Pressure Data

Miller [10], states, "The focus of this paper is to introduce a more robust method for relating the reference frames of the plantar pressure mat and the motion capture system."

System Used: HR Mat

The author says of the measurements obtained from the HR Mat,



With FootMat software it's easy to identify any asymmetries in anterior-posterior and medial-lateral weight bearing. Center of Pressure is another calculation the software provides.

Note: Software image does not contain data from the research article. Image displays sample data from Tekscan software.

"A novel, robust method of synchronizing motion capture and plantar pressure data was created that allows for motion capture markers to be projected onto the plantar pressure mat for accurate subdivision of the foot. Validation studies showed that spatial synchronization of the plantar pressure and motion capture systems was determined to be accurate within 1 sensel."

The author conclude, "The methods presented here are an improvement over previous techniques of synchronizing motion capture and plantar pressure data. Unlike the previous method, the position and orientation of the plantar pressure mat are arbitrary during data collection. In addition, the plantar pressure mat does not have to remain stationary throughout the duration of each motion capture trial. The only requirements are that the pressure mat be located within the motion capture volume and that three motion capture markers be attached to the pressure mat. The method is inexpensive and straightforward to implement and will further facilitate the use of plantar pressure studies."

Physical Therapy

Physical therapists give their patients exercises and stretches to improve their conditions. With Tekscan's in-shoe and floor mat pressure measurement systems, it's easy to compare before and after therapy results side-by-side. The objective information from these systems can provide confidence in developing treatment plans or evaluating the effects of rehabilitation. The following article demonstrates using the F-Scan system to evaluate the effects of stretching exercises on specific muscles.



Physical therapist works with elderly patient on gait and balance

The Effect of Calf Muscle Stretching Exercises on Ankle Joint Dorsiflexion and Dynamic Foot Pressures, Force and Related Temporal Parameters

In Macklin et al. [11] the authors state the purpose as, "To investigate the effect of calf muscle stretching on ankle joint dorsiflexion and subsequent changes within dynamic forefoot peak plantar pressures (PPP), force and temporal parameters."

The authors comment on typical methods of treatment, "To reduce the pathological pressures and forces and improve dynamic gait, calf stretching exercises are commonly prescribed and are probably the most common clinical approach to treating an ankle joint equinus."

System Used: F-Scan System

Regarding the methods used for the F-Scan data analysis, the authors comment:

"The middle three steps from the recorded F-Scan trials were used to extract the pressure and temporal data. Using the mean result of three steps has previously been shown to produce excellent reliability."

Macklin et al. concluded, "Findings indicated that the calf stretching program increased ankle joint dorsiflexion significantly (from 5° to 16°, p≤0.05). The adaptive kinetics brought about by the increased ankle joint range of motion included significantly increased forefoot PPP and maximum force during stance phase but decreased time between heel contact and heel lift and total stance phase time."

Association of Planus Foot Posture and Pronated Foot Function with Foot Pain: The Framingham Foot Study

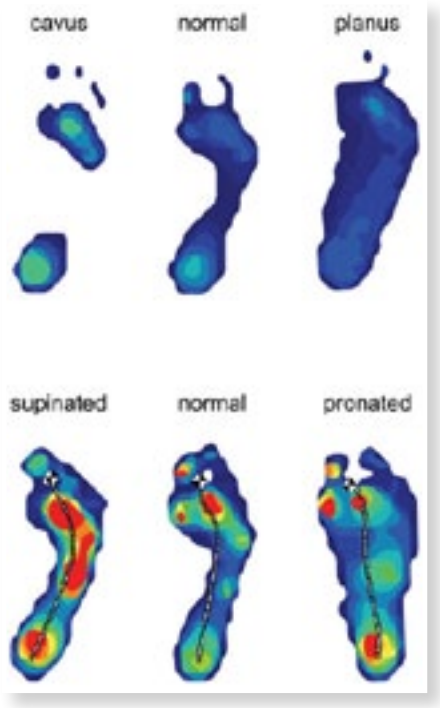
Menz et al. [12] state "The objective of this study was to evaluate the associations of foot posture and dynamic foot function to foot pain in men and women who participated in the Framingham Foot Study."

System Used: MatScan

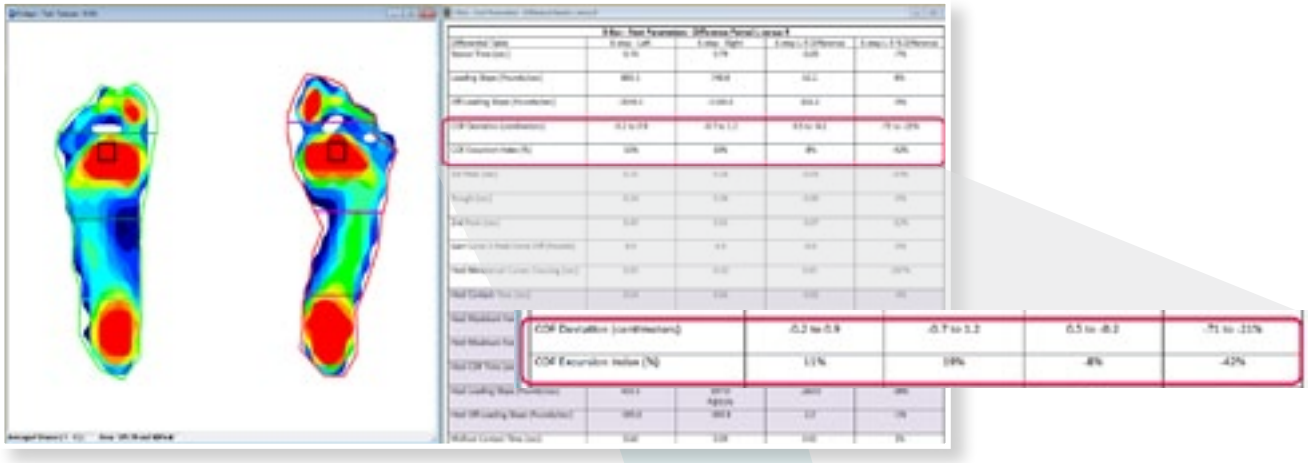
The authors' comment on the approach to the study, "Data were collected on 3,378 members of the Framingham Study cohort who completed foot examinations in 2002–2008. Foot pain (generalized and at 6 locations) was based on the response to the following question: 'On most days, do you have pain, aching or stiffness in either foot?' Foot posture was categorized as normal, planus, or cavus using static pressure measurements of the arch index. Foot function was categorized as normal, pronated, or supinated using the center of pressure excursion index from dynamic pressure measurements."

The authors state in the research article, "Foot Function was assessed by calculating the center of pressure excursion index (CPEI) of the walking trials."

From the measurements obtained with the MatScan System, the authors conclude: "In summary, this is the first population-based investigation to examine the associations of foot posture and function to foot pain using objective biomechanical measurements and it provides evidence of an association between planus foot posture, pronated foot function, and foot symptoms. As foot function is modifiable with footwear modifications and orthoses, such interventions could potentially play a role in both the treatment and prevention of foot pain."



Pressure profiles were used to classify per the 6 common foot types below (the Peak Pressure profiles are presented below the definitions). Image source [12]*



In the FootMat software, the COF Deviation and COF Excursion Index are calculated and displayed as is highlighted in the table (red rectangle). COF = Center of Force.

Note: Software image was not taken from the research article.

Tekscan Systems in the Gait Lab

As you've seen throughout this eBook, a gait lab has many different uses for Tekscan technology. Tekscan's Systems for evaluating foot function, gait, fit and function of prosthetics or balance and sway have proven to be reliable and provide objective information. Information derived from Tekscan's Pressure Measurement Systems can be used similarly to that from a force plate. In addition to their ease of set-up compared to a force plate, the pressure measurement systems provide unique information. The ability to segment of the foot allows for a more detailed analysis.

With portable systems, you can collect information in the lab or transport to real-life environments. The application specific software provides biomechanical information for enhanced decision-making and research outcomes. However, to get a full biomechanical picture, it's important to be able to evaluate various types of data simultaneously. With triggering and synchronization abilities, Tekscan Systems make this possible.

If you are interested in receiving for more information about Tekscan's Pressure Measurement Systems, contact us at info@tekscan.com or 617-464-4281

References

[1] Kim, S., Hwangbo, G. The effect of obstacle gait training on the plantar pressure and contact time of elderly women. Archives of Gerontology and Geriatrics 2015 May-June; 60(3):401-4. http://www.ncbi.nlm.nih.gov/pubmed/25770064

[2] Bohannon, R., Horton, M., Wikholm, J. Importance of four variables of walking to patients with stroke. International Journal of Rehabilitation Research 1991;14(3):246–50. http://www.researchgate.net/publication/21218032_Importance_of_four_variables_of_walking_to_patients_with_stroke

[3] Yang, J., Ahn, N., Kim, D.H., Kim, D.Y. Plantar pressure distribution during robotic-assisted gait in post-stroke hemiplegic patients. Annals of Rehabilitation Medicine 2014 April;38(2):145–52. http://www.ncbi.nlm.nih.gov/pubmed/24855607

[4] Bayouk, J., Boucher, J., Leroux. A. Balance training following stroke: effects of task-oriented exercises with and without altered sensory input. International Journal of Rehabilitation Research 2006;29(1):51–9. http://www.ncbi.nlm.nih.gov/pubmed/16432390

[5] Coda, A., Carline, T., Santos, D. Repeatability and reproducibility of the Tekscan HR-Walkway system. The Foot 2014 June;24(2):49–55. http://www.ncbi.nlm.nih.gov/pubmed/24703061

[6] Cooper, A., Chhina, H., Howren, A., Alvarez, C. The contralateral foot in children with unilateral clubfoot, is the unaffected side normal? Gait & Posture 2014 July;40(3):375–80. http://www.gaitposture.com/article/S0966-6362%2814%2900523-2/fulltext?dialogRequest

[7] Salazar-Torres, J., McDowell, B., Humphreys, L., Duffy, C. Plantar pressures in children with congenital talipes equino varus – A comparison between surgical management and the Ponseti technique. Gait & Posture 2014 January;39(1):321–27. http://www.ncbi.nlm.nih.gov/pubmed/23973353

[8] Lawson, B., Aguilar, F., Knop, L., Goehler ,C. The effects of shoe architecture on heel impact forces during gait. Paper from the Proceedings of the ASME 2013 Summer Bioengineering Conference; Sun River, OR, June 26-29 2013. http://www.researchgate.net/publication/267617076_The_Effects_of_Shoe_Architecture_on_Heel_Impact_Forces_During_Gait

[9] Farley, K., Niverson, A., Rogge, R. The effects of toning shoes on the postural stability of women. Paper Presented at the 2013 American Society of Biomechanics Conference; Omaha, NE, Sept 4-7, 2013. http://www.asbweb.org/conferences/2013/abstracts/85.pdf

[10] Miller, A. A new method for synchronization of motion capture and plantar pressure data. Gait & Posture 2010 June;32(2):279–81. http://www.ncbi.nlm.nih.gov/pubmed/20541413

[11] Macklin K, Healy A, Chockalingam N. The effect of calf muscle stretching exercises on ankle joint dorsiflexion and dynamic foot pressures, force and related temporal parameters. The Foot 2012;22(1):10–17. http://www.ncbi.nlm.nih.gov/pubmed/21944945

[12] Menz, H, Dufour, A., Riskowski, J., Hillstrom, H., Hannan, M. Association of planus foot posture and pronated foot function with foot pain: the Framingham foot study. Arthritis Care & Research 2013 December;65(12):1991-99 http://www.ncbi.nlm.nih.gov/pubmed/23861176

* Indicates images were taken directly from the cited research article.

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