Update

Plantar Pressure Assessment

Measurements of plantar pressure provide an indication of foot and ankle function during gait and other functional activities, because the foot and ankle provide both the necessary support and flexibility for weight bearing and weight shifting while performing these activities.[1–3] Although plantar pressure data have been recognized as an important element in the assessment of clients with diabetes and peripheral neuropathy, information derived from plantar pressure data also can assist in determining and managing the impairments associated with various musculoskeletal, integumentary, and neurological disorders.

The use of force platforms is the method most commonly used to assess the interaction of the foot and the supporting surface. Although the force platform provides valuable information regarding both the vertical and shear components of the ground reaction force, it provides little information on how the plantar surface of the foot is loaded with respect to the supporting surface. When evaluating patients, atypical amounts of loading or patterns of loading may be reflective of a systemic or localized lower-extremity pathology and may be indicators (risk factors) for or predictors of further pathology or worsening of the existing pathology.[4] In addition, force platforms have very specific requirements for attachment to the supporting surface on which data collection will occur. Such is *not* the case with numerous commercially available systems for measuring plantar pressure (eg, Emed sensor platform,* Pedar insole system,* F-Scan system,† Musgrave footprint system‡). Thus, plantar pressure measurement systems offer the clinician a high degree of portability, permitting utilization among multiple clinic sites.

[Orlin MN, McPoil TG. Plantar pressure assessment. *Phys Ther*. 2000;80:399–409.]

Key Words: *Foot and ankle, Gait, Measurement systems, Plantar pressure, Transducers.*

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Pressure (p) (also called "stress") is defined as force (f) per unit area (a) (ie, p=f/a).[5] *Force*, when measured using a force platform, is the net result of the 3 components of the ground reaction or resultant force acting on the foot.[6] The 3 components of the ground reaction force are in the fore-aft, medial-lateral, and vertical directions. When assessing plantar pressure, a discrete sensor or a matrix of multiple sensors is used to measure the force acting on each sensor while the foot is in contact with the supporting surface. The magnitude of pressure is then determined by dividing the measured force by the known area of the sensor or sensors evoked while the foot was in contact with the supporting surface.[7] The System International (SI) unit of force is the newton, and the SI unit of pressure is the pascal. A *pascal* is defined as the pressure experienced when a force of 1 N is distributed over an area of 1 m^2.[8] Pressure values can be reported in newtons per square centimeter, pounds per square inch, or kilograms per square inch, but kilopascals or megapascals are the preferred units of measurement.

Data obtained from a plantar pressure assessment can be used for the evaluation and management of patients with a wide variety of foot impairments associated with neurological and musculoskeletal disorders, which can affect both adult and pediatric patients.[9–12] The assessment of plantar pressures can be included as part of a full laboratory gait analysis, or it can be done independently in either a laboratory or a clinical setting to help direct treatment options and for patient education. When plantar pressure values are determined to be atypical, the information can be used to modify a patient's management program through alterations in footwear, foot orthoses, exercise programs, and restrictions in the amount of weight bearing.

Information obtained from pressure systems is also useful from a research perspective to address many questions regarding the relationship between plantar pressure and lower-extremity posture. Because standing and walking are not the only activities in which plantar pressures are generated, investigators have compared various aerobic,[13] dance,[14] and functional activities[15] with level walking to provide insight into the stresses that these activities impart to the foot and lower extremity.

Plantar pressure data can assist the physical therapist in managing the impairments associated with musculoskeletal, integumentary, and neurological disorders.

This update on plantar pressure assessment has 3 purposes: (1) to provide the reader with an understanding of current technology and terminology used when measuring plantar pressures, (2) to explain the use of plantar pressure technology in the clinical setting, and (3) to review articles that illustrate how physical therapists have utilized plantar pressure measurements in the assessment and management of impairments associated with disorders of the neurological, integumentary, and musculoskeletal systems. For an extensive review of the development of plantar pressure assessment, the reader is referred to the articles by Alexander et al[16] and Cavanagh et al.[17]

Current Technology Used to Assess Plantar Pressures

Measured Variables

The typical components of a system used to measure plantar pressures include the measuring device, which consists of sensors in a platform or insole configuration; a computer for data acquisition, storage, and retrieval for analysis; and a monitor for displaying data. Various software packages are available that allow the clinician to divide the plantar surface of the foot into numerous regions to permit the analysis of data, as is illustrated in Figure 1. The most common variables of interest include peak and average pressure, force, and area. Peak pressure plots represent the highest pressure value recorded by each sensor over the entire stance phase.[7] Figure 2 depicts a peak pressure matrix obtained during walking for a child with juvenile rheumatoid arthritis (left) and a child of similar age without known pathology (right).

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† Tekscan Inc, 307 W First St, Boston, MA 02127.

‡ WM Automation and Preston Communication Ltd, North Wales, United Kingdom.

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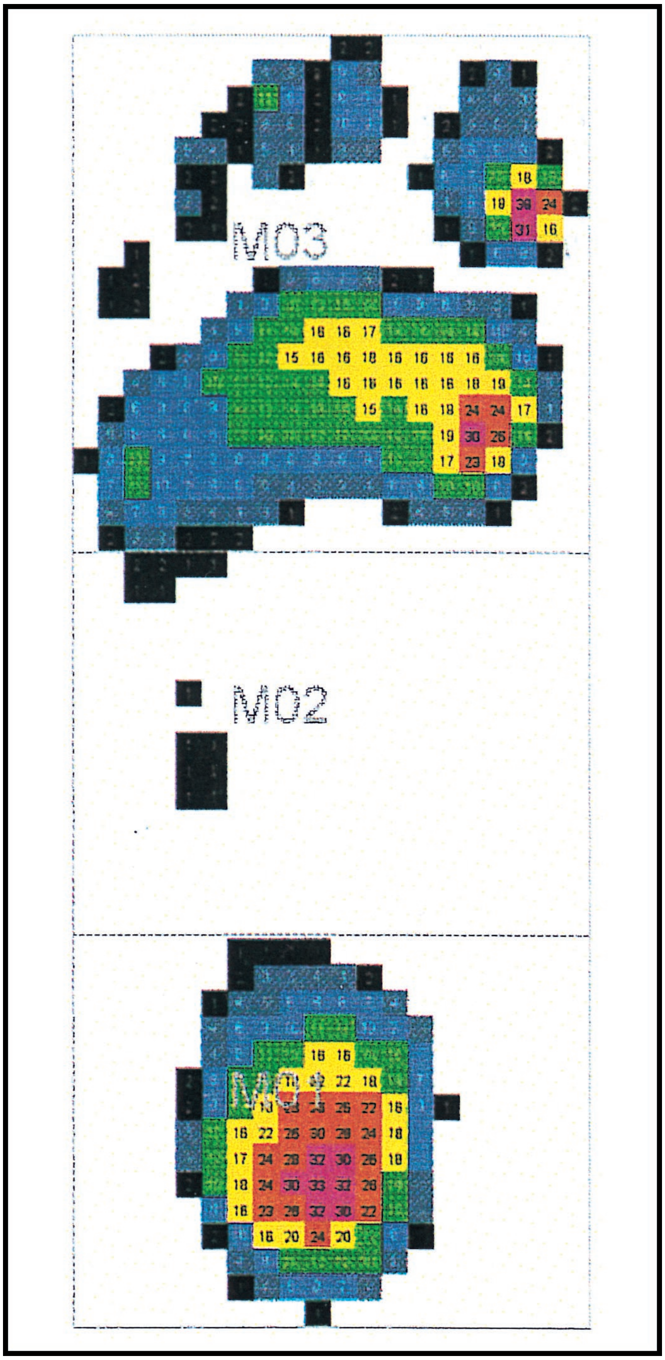

Figure 1.
A peak pressure plot divided into 3 regions of interest: hindfoot, midfoot, and forefoot.

The software provides values for pressure and a user-specified color scheme to graphically display the pressures acting on the plantar surface of the foot. In Figure 2, the colors red and purple denote the highest pressures, and the green, blue, and black colors represent the lower pressure values. Peak pressures are often of interest in determining the effectiveness of a cushioned foot orthosis in decreasing pressures under a sensitive metatarsal head, whereas average pressure values provide the clinician with an understanding of typical pressure acting on a specific anatomical region during the walking cycle.

Area refers to the amount of surface contact between the plantar surface of the foot and the sensor. In the peak pressure plot shown in Figure 2, there is a marked variation in the area of contact with the ground between the 2 children. The area beneath the force-time curve as well as the pressure-time curve can also be determined and is referred to as the integral of the curve or impulse (Fig. 3). The impulse can be of use to the clinician in understanding the amount of force or pressure that has been applied over time, in this case the duration of foot contact.[18] Commercially available software also permits the sequential viewing of both pressure and area, beginning at initial contact and ending when the foot leaves the ground, as illustrated in Figure 4. Three-dimensional displays of plantar pressure data can be effective when educating the patient regarding regions of high pressure on the plantar surface of the foot.[7] Figure 5 illustrates 3-dimensional pressure plots for a child with juvenile rheumatoid arthritis (left plot) and for a child of a similar age without known lower-extremity pathology (right plot). The 3-dimensional plots provide a graphic illustration of the extreme pressures acting under the fourth metatarsal head region of the child with juvenile rheumatoid arthritis in comparison with the other child. Such illustrations can also be effective in the patient education of individuals with diabetes and peripheral neuropathy to assist in their understanding of potential sites of ulceration.

System Specifications

A limitation when using most pressure assessment systems is that the force value measured by the sensor and used in the calculation of pressure is normal force or a force that is perpendicular to the sensor surface. Normal force can be considered vertical force when a platform, fixed to the supporting surface, is used for data collection. When a sensor insole is placed in a shoe, however, normal force may only be considered vertical force during that portion of the stance phase when the entire foot is in contact with the supporting surface.[17] In general, the sensors used for pressure measurement do not measure the fore-aft or medial-lateral shear forces that are obtained using force platforms.[16] This is an important point, because shear forces are considered to be an important factor in the development of plantar ulcers in clients with diabetic neuropathies.[7] Cornwall and McPoil[19] were able to predict fore-aft or anterior-posterior shear force with a pressure sensor platform using a combination of peak force, time to peak pressure, and stance phase duration. To accomplish this, the authors attached a pressure sensor platform to a force platform and collected data with both systems recording simultaneously at a similar sampling frequency. No

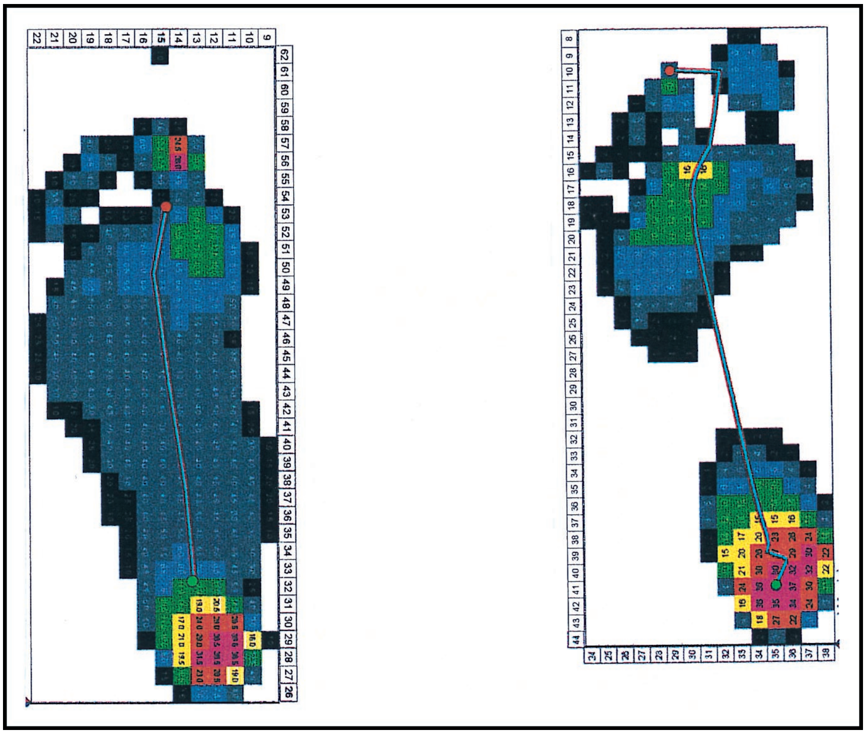

Figure 2.
Peak pressure plots for 2 children of similar ages. Left plot is from a child with juvenile rheumatoid arthritis, and right plot is from a child without known pathology.

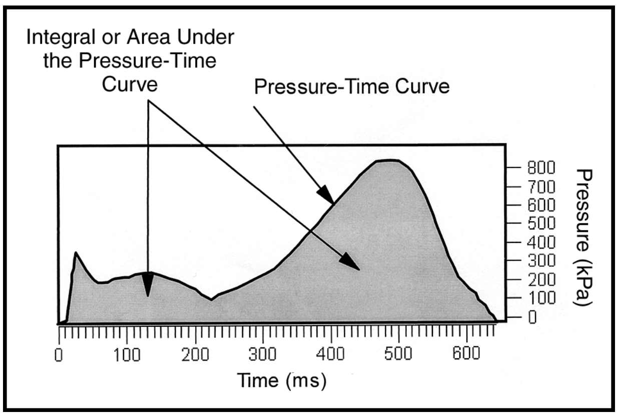

Figure 3.
An illustration of the integral or the area under the pressure-time curve.

researchers to date, however, have been able to determine the medial-lateral shear force component using a pressure sensor platform.

Those specifications that should be considered when selecting a system for measuring pressures include resolution, sampling frequency, reliability, and calibration. *Resolution* refers to both the size and number of sensors used in the system.[6] The higher the resolution of the system, the greater the number of sensors. The size of the sensor is also important because different size sensors can alter the pressure reading, as pressure is dependent on both force and area. A force applied to a large sensor will not provide the same pressure reading as the same force applied over a small sensor. This is because the spatial resolution of the system is not high enough. For example, if a vertical force of 50 N were applied to a 1-cm^2 sensor, the resulting pressure would be 500 kPa. If the same force of 50 N were applied to 4-cm^2 sensor, however, the resulting pressure would be only 125 kPa. Considering the tremendous anatomical variations in the size of the metatarsal heads, hallux, and toes based on foot size, the resolution of the pressure measurement system becomes an important consideration for the clinician. Resolution becomes even more critical when assessing the plantar pressures in children with small foot sizes.

Sampling frequency is an important factor in determining the temporal resolution of the system. Sampling frequency is the number of samples measured by each sensor per second and is recorded in cycles per second or hertz.[6] Mittlemeier and Morlock[20] examined the effect of plantar pressures obtained using 4 different sampling frequencies and reported that pressure data collected between 45 and 100 Hz were adequate for walking. Most commercially available systems (eg, Emed sensor platform, Pedar insole system, F-Scan system) offer sampling rates between 50 and 100 Hz. For higher-speed activities, such as running, sampling frequencies of 200 Hz or greater are often required.[21]

Reliability of the measurements obtained with the pressure sensor are critical for an accurate measurement. Hughes et al[22] suggested that using the average of 3 to 5 walking trials enhances the reliability of the pressure measurement, although 100% replicability cannot be expected because of inherent differences in each walking trial. Several researchers[22–24] have evaluated the reliability of measurements obtained for different sensor technologies used for both platform and in-shoe pressure measurement systems. Because they reported variations in the reliability of measurements obtained with the different systems available for measuring plantar pressures, it is critical for the clinician to be aware of the reliability (error) of the system he or she has selected for use.

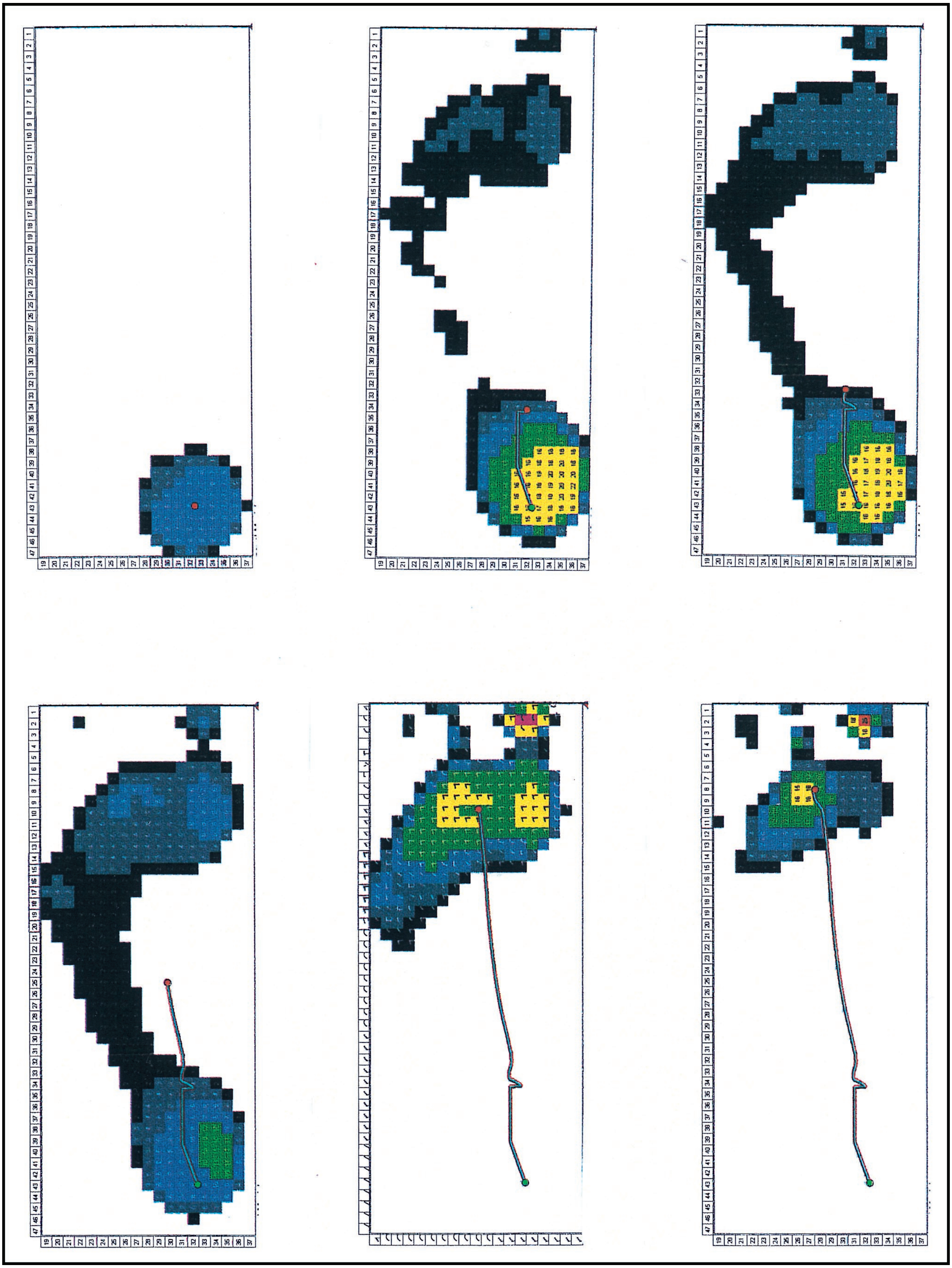

Figure 4.
Sequence of pressure plots over the entire stance phase of walking.

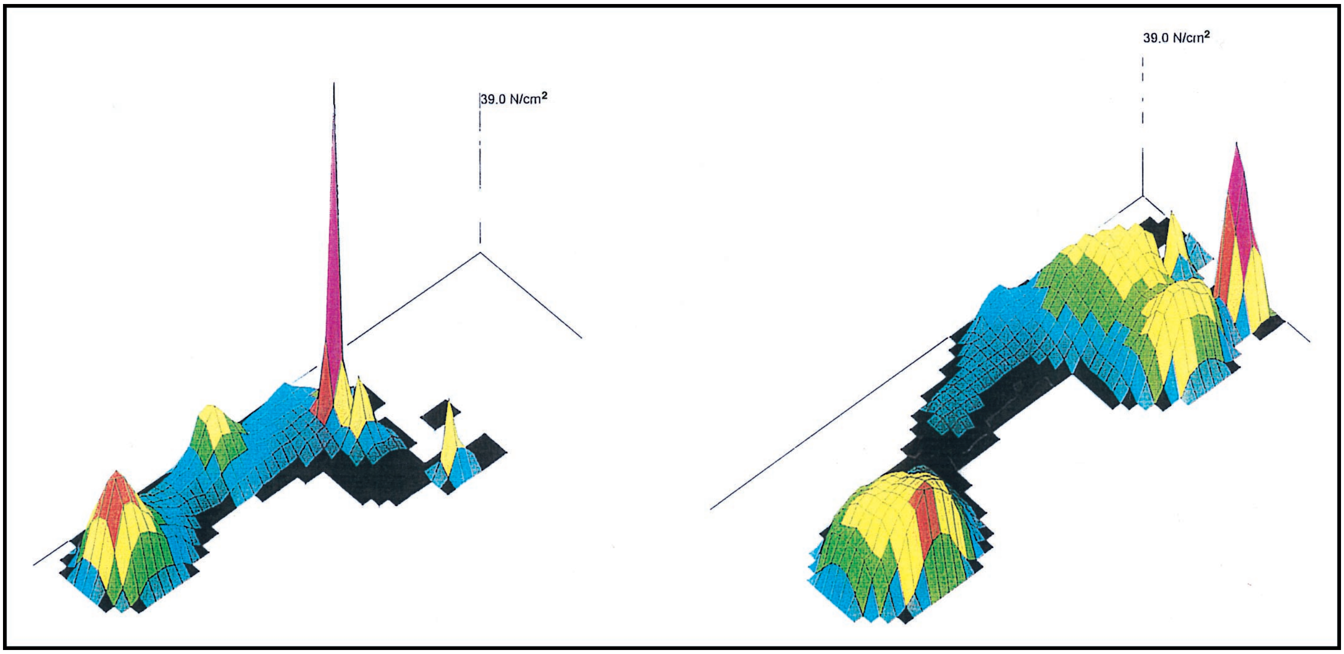

Figure 5.
Three-dimensional peak pressure plots for 2 children of similar ages. Left plot is from a child with juvenile rheumatoid arthritis, and right plot is from a child without known lower-extremity pathology.

Calibration is important for establishing the validity of measurements of both force and pressure. Although a system may give consistent repeated measurements, that is, have reliability, the measurements may not provide an accurate representation of the actual force or pressure acting on the plantar surface of the foot because the actual pressure values provided, even though repeatable, may not be accurate. One method for calibrating the sensors in both platform and insole systems is to place either device under a rubber bladder that is then filled with compressed air at several known levels of pressure. The use of this type of air bladder system allows each sensor to be uniformly loaded and permits the generation of a calibration curve for each sensor or group of sensors in a matrix. Having a patient stand on the insole or platform as a method of calibration may not be sufficient because each sensor is not uniformly loaded, and some sensors may not be loaded at all, generating no calibration data for those sensors.

Measurement Technology

Plantar pressures can be measured using a variety of instruments, including force-sensing resistors (FSRs),[17] hydrocells,[21] microcapsules,[25] projection devices,[26] pedoscopes,[27] and capacitance transducers,[28] as well as by critical light deflection.[16] Many of these instruments can be used as discrete sensors or to create a matrix of multiple sensors. It is important for the clinician to be aware of the features associated with these devices prior to using them for data collection.

Discrete measurements utilize individual pressure transducers positioned at specific anatomical locations on the plantar surface of the foot. Thus, the use of discrete transducers requires the clinician to make an *a priori* decision regarding the appropriate placement for optimal data collection. Once the locations have been determined, the transducers are either held in position on the bottom of the foot with adhesive tape or embedded into an insole of similar material properties. Because only a small number of sensors are used at any one time, a major advantage for using discrete measurements is a higher sampling rate, in some cases up to 200 samples per second.[21] Thus, discrete measurements are often selected for high-speed activities such as running or various sport movements. Although discrete sensors are usually easy to use and affordable, several issues must be addressed when using this method of pressure data collection. The discrete sensor can act as a foreign body in the shoe, thus acting as an irritant within the shoe as though it were a flat stone.[17] Furthermore, the lack of consistency between the material used to fabricate the sensor and the skin can cause an "edge" effect, which can lead to falsely elevated pressure values. Finally, the discrete sensors can migrate from their original position during dynamic activity secondary to shear stress at the foot-shoe interface.[17] Thus, the actual pressure values recorded may not reflect the desired anatomical landmark originally selected by the clinician.

Matrix measurements use an array of sensors organized in rows and columns rather than an individual discrete sensor. Thus, matrix measurements can assess the distribution of pressures acting over the entire plantar surface of the foot simultaneously. A major advantage when using a matrix measurement is that no *a priori* decision is required prior to the pressure assessment. In addition, a larger plantar surface area can be assessed at once.

Microcapsules. The technology involving the use of microcapsules was developed at the Gillis W Long National Hansen's Disease Center in Carville, La.[25] Small dye-filled capsules sandwiched between 2 layers of thin foam, shaped like a sock, were positioned over a patient's foot prior to donning the shoe. As the patient walked, the capsules would fracture at a certain load, and dye from the crushed capsules would be released into the foam layers. The release of the dye would leave an observable impression of the areas on the plantar surface of the foot with the highest pressures. This use of microcapsules represented one of the first attempts to provide a cost-effective method of obtaining an assessment of in-shoe plantar pressures, but attempts to quantify the different levels of pressure were unsuccessful. In addition, the application of the sock containing the microcapsules was time-consuming, and microcapsules often fractured when attempting to don the shoe.

Projection devices. This type of device consists of a rubber mat with repeating patterns of small projections, with the surface of each projection having several heights. The mat is inked and then covered with paper. When a load is applied to the mat by the patient, the most ink will be deposited at the locations of highest pressure because all the layers of the mat are compressed by the applied load. Harris and Beath[26] first reported using this type of device in attempting to classify the foot structure of Canadian soldiers. One currently available projection device is the Foot Imprinter.[§] The mat type of projection device is suitable for a qualitative description of the pattern of plantar pressure, but this type of device cannot be used to quantify the magnitude of plantar pressures.

Podoscope. The podoscope was designed to provide the clinician with a visual image of the pressure distribution over the plantar surface of the foot during standing or during single-limb stance.[27] The podoscope consists of a wooden box with a glass top. The glass top is illuminated on each side by fluorescent lights. A mirror angled at approximately 45 degrees is positioned below the glass to provide a view of the plantar surface of the foot. In order to record the patient's pattern of pressure distribution, the image as viewed through the mirror can be photographed, videotaped, or traced on paper. The podoscope provides the clinician with a quick and colorful presentation of high-pressure areas, but this device does not permit the quantification of pressure values.

Capacitance transducers. Nicol and Henning,[28] in 1986, first described the use of a capacitance transducer for the measurement of plantar pressures. A capacitance transducer consists of 2 plates made of a conducting material separated by a nonconducting or insulating layer termed a "dielectric." The transducer stores an electrical charge, and the 2 plates are compressed when force is applied, causing the distance between the plates to decrease.[16] As the distance between the plates decreases, the capacitance increases, and the resulting change in voltage is measured.[16] Novel Electronics uses a matrix of multiple capacitance transducers in the Emed sensor platform and the Pedar insole system. Pressure measurement systems using capacitance transducers utilize a calibration curve that is developed for each sensor in the matrix and permits the quantitative assessment of pressure. A disadvantage of using a capacitance transducer for in-shoe pressure measurement is that the sensor insole is thicker (approximately 2 mm) in comparison with other types of sensors.

Force-sensing resistors. The FSR is a very thin layered device with metal patterns printed on 2 Mylar sheets,[‖] with a conductive polymer layer embedded between the 2 sheets.[17] The conductive layer reduces resistance to the flow of electrons as the pressure between the Mylar layers increases.[17] This pressure between the Mylar layers causes the resistance to decrease. The output of devices using this type of sensor technology can be either force or pressure. The force measured, however, is vertical force. Tekscan uses the FSR technology in a matrix array for both a floor-mounted platform and an in-shoe insole that are marketed as the F-Scan system. The Musgrave footprint system, which is manufactured in the United Kingdom, also uses a matrix of FSR sensors for a floor-mounted platform.

Critical light reflection. The hardware necessary to use the critical light reflection technique for the measurement of plantar pressures consists of a plastic sheet, a side-illuminated rectangular glass plate with force transducers mounted at each corner, a video camera, and a microcomputer for data storage. The inferior surface of the plastic sheet has multiple tiny knobs, which flatten against the glass surface when pressure is applied.[16] As the plastic sheet is compressed against the glass surface, the intensity of the light illuminated through the glass is changed.[16] These intensity changes are recorded by the video camera, and the magnitude of force applied to the glass surface is determined from the force transducers.

[§] Apex Foot Health Industries Inc, 170 Wesley St, South Hackensack, NJ 07606.

[‖] EI du Pont de Nemours & Co Inc, 1007 Market St, Wilmington, DE 19898.

Based on the light intensity changes and the forces measured, the microcomputer can determine the pressures acting on the plantar surface of the foot.[16] Commercially, this system has been referred to as the Pedobarograph,[#] and its use with a clinical population has been described in detail by several authors.[4,10,29–31]

Hydrocell. The hydrocell consists of a discrete piezoresistive sensor contained in a fluid-filled cell, which is embedded into an insole. When a load is applied to the hydrocell, the applied force causes increased resistance within the water environment of the hydrocell.[21] The piezoresistive sensor within the cell generates an electrical charge as a result of this increased resistance.[21] Because of the qualities of the piezoelectric sensor, the hydrocell has been purported to measure shear forces as well as vertical forces, although further research is necessary to confirm this quality of the hydrocell. Currently, the Parotec system** utilizes this technology by embedding 24 individual hydrocells into a flexible insole. Hydrocell technology permits the quantification of pressures.

Examples of low-cost measurement devices include projection devices, microcapsules, and podoscopes. The advantages of these devices, in addition to their low cost, are that they are readily available to the clinician and require minimal technical training or expertise to use. The cost of these systems is usually less than $200. The primary disadvantage of these low-cost devices is that they cannot be used to quantify the magnitude of plantar pressures. Although the clinician can effectively use these systems to identify areas of high pressure on the plantar surface of the foot and to educate the patient about areas of increased pressure, they cannot be used to quantify the actual pressure values.

Examples of high-cost devices include hydrocells, capacitance transducers, FSRs, and the hardware necessary for the use of the critical light reflection technique. Some advantages of these systems are the quantification of pressures and the ability to analyze specific regions on the plantar surface of the foot to determine pressure, force, impulse, and area. The cost of these systems ranges from $15,000 to over $50,000, depending on the accessories and analysis software purchased with the system.

Selection of Platform Versus In-Shoe Data Collection Methods

Although the manufacturers of pressure measurement systems use the various technologies previously discussed for developing both their platform and in-shoe measurement systems, specific issues associated with in-shoe versus platform data collection should be considered by the clinician when determining which method will be selected. The advantages of using a platform device typically include a greater number of sensors, thus a higher resolution, and the fact that the pressure sensors are always positioned parallel to the supporting surface to provide a "true" vertical force measurement. The problems associated with using a platform or mat system for data collection include the large number of steps required to collect data and the targeting of the platform sensor surface by the patient.

The traditional method for collecting data using a platform system has been termed the "mid-gait" technique.[32] The mid-gait technique requires that the patient walk across a walkway, usually at least 9 m in length, while pressure data are collected from a single foot contact over the sensor platform. Considering that previous studies[22] have indicated that pressure data from at least 3 to 5 steps are required to establish replicability, multiple barefoot walking trials across the walkway are required for data collection. Patients with diabetes and neuropathy could be placed at risk when collecting pressure data using the mid-gait method because the numerous steps required for the mid-gait method can actually increase the possibility of plantar ulceration.[7] In addition, patients with neurological impairment may have difficulty contacting the platform because of proprioception and coordination problems.[7]

In an attempt to counteract the problems associated with the mid-gait method, Rodgers[33] recommended using pressure data collected using the mid-gait and 1-step methods for patients who are at risk for plantar ulceration. In a later study, Meyers-Rice et al[32] described a 2-step method that was superior to the 1-step method in replicating the pattern of plantar pressures attained when using the mid-gait method because the 2-step method provided pressure values that were more similar to those obtained with the mid-gait method.

Another problem associated with platform measurements is the "targeting" of the platform by the patient. The term "targeting" indicates that the patient has altered the walking pattern so that he or she can place the foot in contact with the platform.[23] Unfortunately, targeting may result in alteration of the patient's typical pressure pattern. The use of in-shoe data collection methods is thought to eliminate the problem of targeting, because all the patient is required to do is walk normally. Furthermore, in-shoe data collection provides the clinician with information about pressures occurring within the shoe, at the shoe-foot interface. In-shoe pressure measurement also permits the clinician to study other functional activities, such as dancing, because the

[#] Baltimore Therapeutic Equipment Co, 7455-L New Ridge Rd, Hanover, MD 21076.

** Paromed Medizintechnik GmbH, Munich, Germany.

pressure-sensing device is located within the shoe.[17] In-shoe pressure measurement is especially important when assessing the effect of specially designed footwear or foot orthoses prescribed to modify the pressures acting on the plantar surface of the foot. Based on the analysis of in-shoe pressure data, the clinician can modify the footwear or orthoses to maximize their benefit to the patient.

Although in-shoe data collection would appear to be a good choice for the clinician, there are several problems associated with this technique. Because the number of sensors that can be incorporated into the pressure sensor insole is less than the number of sensors used in a platform system, the resolution is usually diminished. The sensor insoles are more susceptible to mechanical breakdown because transducer cables connecting the sensors to the computer can be bent or stretched as they exit the shoe.[23] Individual sensors can also be damaged by continuous repetitive loading. In addition, the hot, humid, and usually contoured environment within the shoe can affect the reliability and validity of measurements of the sensor's performance.[17] As the sensor insole can only measure "normal" force because of the position of the insole sensor within the shoe relative to the supporting surface,[23] the measurement of "true" vertical does not occur during the initial and late portions of the walking cycle. Although platform and in-shoe data collection methods both have unique advantages and disadvantages, clinicians should base their selections on the characteristics and functional capabilities of their patients as well as on the desired activity or assistive device they want to study.

Clinical Applications of Plantar Pressure Assessment

Several previously published studies[29,31,34–48] illustrate how physical therapists have utilized plantar pressure measurements for the assessment and management of lower-extremity and foot disorders associated with the neurological, integumentary, and musculoskeletal systems.

The effectiveness of ankle-foot orthoses has been the primary focus of plantar pressure studies in both adult and pediatric patients with neurological disorders. Mueller and colleagues[34,35] have investigated the effect of tone-inhibiting dynamic ankle-foot orthoses on the foot-loading patterns of adults with hemiplegia. The results of these studies suggested that ankle-foot orthoses generated increased force, area, and impulse through the hindfoot, midfoot, and forefoot during contact with the supporting surface. Kirkeide et al[36] have reported using plantar pressure measures to determine the effectiveness of hinged versus rigid ankle-foot orthoses on the loading patterns of children with spastic diplegia during walking. In these studies,[34–36] the use of plantar pressure measures aided the investigators in understanding how the various plantar regions of the foot were loaded with and without orthotic intervention. Furthermore, the use of plantar pressure measures permitted the authors to delineate which types of orthoses were most effective in producing a more typical pattern of foot loading during walking. In the study conducted by Kirkeide et al, the use of an in-shoe pressure measurement system also increased the efficiency and ease of data collection. Because their subjects were young children with cerebral palsy and they used an in-shoe pressure system, the number of trials that would have been required to obtain measurements with a platform system while the children were walking was reduced.

The primary focus of researchers obtaining plantar pressure measurements for musculoskeletal disorders of the lower extremity and foot has been to investigate the effect of foot orthoses and shoe modifications, as well as various materials used in the clinic to cushion the forefoot. Single-patient case reports, using in-shoe pressure measurement, have assessed the effectiveness of orthotic posting,[37] padded hosiery,[38] and various materials used to fabricate foot orthoses[39,40] designed to decrease the plantar pressures acting beneath the forefoot. Researchers using platform pressure measurements have evaluated various types of insole materials[41] and internal and external shoe modifications.[42,43] The information attained from these studies can be used to assist clinicians in determining the appropriate type and amount of posting required for foot orthoses as well as the amount of pressure reduction that can be expected when using either padded hosiery or various types of insole materials. This information can also be used to assist clinicians in determining the most cost-effective approach for managing patients with various musculoskeletal foot and ankle disorders.

Most publications describing plantar pressure measures deal with disorders of the integumentary system. The primary reason for this is the increased risk of plantar surface ulceration in the feet of patients with diabetes and neuropathy who also have elevated plantar pressures.[29,31] The majority of these studies have focused on the effect of therapeutic footwear,[44] insoles designed to decrease high-pressure regions on the plantar surface of the foot,[40,45] and shoe modifications.[46] Because total contact casting, applied with little or no padding, has been purported to be an effective means of healing plantar ulcers, Birke et al[47] assessed the plantar pressures within a total contact and typical padded cast to demonstrate that padding was not a factor in reducing the pressures acting on the plantar surface of the foot. The information gleaned from these studies has provided clinicians with data regarding the effect of shoe modifications, therapeutic insoles, and total contact casting in reducing plantar pressures over those plantar regions previously determined to have elevated pressure values. Elevated plantar pressures have been shown to be predictive of potential sites of ulceration. Therefore, this information can be used by clinicians to select the most appropriate treatment strategy for each patient. Mueller and colleagues[48] studied the effect of different hip and ankle walking strategies on lowering forefoot plantar pressures. This was one of the first studies where the modification of a patient's pattern of walking to effect a change in plantar pressures acting on the forefoot was studied. High pressures are a high risk for ulceration in patients with diabetes and neuropathy.

Conclusion

Data obtained from a plantar pressure assessment can be used by the physical therapist in the evaluation and management of adult and pediatric patients with a wide variety of foot and lower-extremity disorders associated with the neurological, integumentary, and musculoskeletal systems. Unlike the force platform, pressure systems measure only vertical force, but they provide the clinician or researcher with information regarding the effects of various interventions, including use of footwear, use of foot orthoses, gait training, and surgical management, on forces and pressures applied to specific locations of the foot.

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