iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 9 **Issue:** VI **Month of publication:** June 2021

DOI: https://doi.org/10.22214/ijraset.2021.35027

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue VI June 2021- Available at www.ijraset.com

Applications of Plantar Pressure Measurement- A Review

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Abstract*: Foot plantar pressure is the pressure field that acts between the foot and the support surface during locomotor activities. Information obtained from such pressure measurement gives us ankle and foot functions during gait and other activities. The ankle and foot provide the required support to do different activities like walking, playing, running etc. Data from plantar pressure measurement is crucial for diagnosing lower limb problems, designing a footwear, sport biomechanics, injury prevention and diagnosis. This paper concentrates on the applications of foot plantar pressure measurement in different fields and its future scope.

Keywords: Applications of plantar pressure measurement, Human Gait cycle, injury prevention, sport biomechanics, foot wear design, foot diagnosis.

I. INTRODUCTION

Plantar pressure is the pressure exerted on the lower extremities of the body due to medial-lateral, fore-aft and vertical forces that acts between foot and the supporting surface. [1, 2,]. In normal human gait cycle, amount of pressure between the plantar surface of the foot and the supporting surface differs from each step of stance phase (HS = Heel strike, FF= foot flat MSt = mid stance, HO = heel off) to each step of swing phase (TO = toe off, IS= initial swing, and MSw = mid swing) [3]

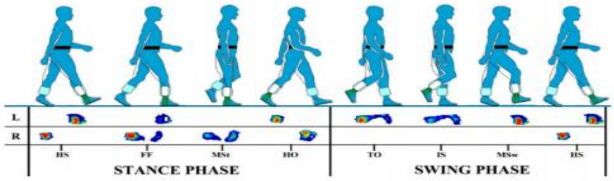

Figure 1 Plantar pressure distribution of right and left leg in stance and swing phase. [3]

Data captured from plantar pressure measurements can be utilized for wide range of clinical applications like evaluating foot impairments associated with musculoskeletal and neurological disorders, foot ulceration, alteration of normal foot function and rehabilitation support system for the same [2-4, 5]. Other applications of plantar pressure assessment include designing of foot insoles to reduce the mechanical pressure on the foot to prevent foot related injuries in normal and obese people with both loaded and unloaded gait [6]. Occasional loaded gait can also have impact of the pressure distribution on foot and may lead to foot impairments [6, 7]. Sports like football, volleyball, cricket, athletics etc., players push their ability to extreme limits. To achieve this extreme limit and to protect their foot from injury they wear customised boots/shoes depending on their plantar pressure measurements [8]. This extreme plantar loading can have huge impact on the pressure of foot and repetitive plantar loading may lead to injuries, discomfort and decreased performance [8, 9]. Pressure measurement is crucial in preventing and treating injuries to developing new products with high biomechanical characteristics to the wearer with high comfortability.

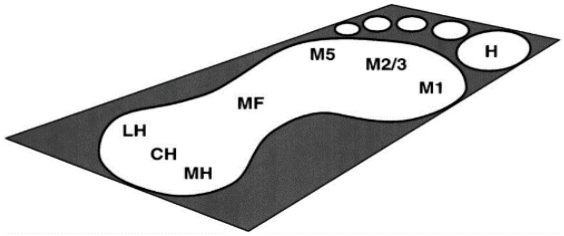

Figure 2 Foot outline with the regions to evaluate foot loading characteristics. MH=Medial heel, CH=Central heel, LH=Lateral heel, MH=mid foot, M1=Medial forefoot (1st Metatarsal), M2/3=Central forefoot (2nd/3rd Metatarsal), M5=Lateral forefoot (5th Metatarsal), H=Hallux

II. APPLICATIONS OF DOMAIN FOR MEASURING PLANTAR PRESSURE

Data obtained from plantar pressure assessments are widely used in different fields. These data provide the pressure on the foot during loaded and unload condition and the region of foot where pressure is high while doing activities. The application domain of measuring Plantar Pressure in different field mentioned in Figure 3.

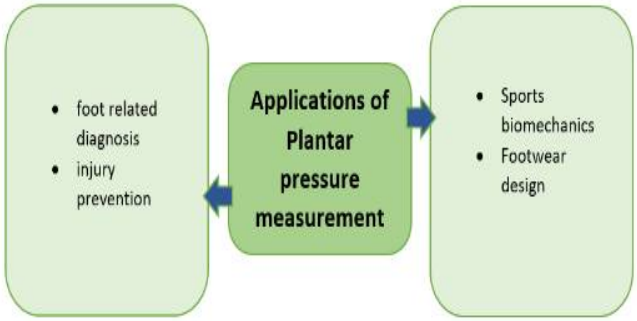

Figure 1 Applications of plantar pressure assessment in different field

A. Foot related pathology diagnosis:

Foot pathologies can influence foot functions negatively and thus lead to impairing gait during daily activity. These pathologies are linked with high or abnormal plantar pressure which can result in asymmetrical pressure distribution between the two feet [3]. Abnormal plantar pressure can be a result of any pathological conditions and some foot impairments can arise due to poor/abnormal pressure distribution. So, pathology and irregular plantar pressure are interconnected in certain aspects. Some disease conditions like diabetes mellitus, hemiparesis/ unilateral paralysis (weakness of one entire side of body), neuropathy (variety of nerve defect) triggers elevated levels of plantar pressure which may ultimately lead to foot impairments, foot pain and foot ulceration [2, 13-15]. In diabetic peripheral neuropathy, a condition where numbness of feet, muscle fragility and even change in foot structure and function occurs. Foot plantar pressure of affected individuals indicated that they are highly prone to foot ulcers at midfoot and forefoot regions. Furthermore, those regions had also displayed excessive dorsiflexion, external rotation and eversion [15]. Another research indicated that patients with diabetes has increased forefoot plantar pressure to abnormally high levels and regular monitoring of foot plantar pressure in the patients with diabetic foot might reveal the toe deformity earlier and ulceration might be prevented [14]. A study on hemiparetic patients, showed lower peak pressures under all anatomical structures and an unexpected medial load in the forefoot. It also supported that peak pressure measures can be used for better understanding of pathological gait mechanisms and provide quantitative, reproducible and objective data that may help in the follow-up of patients [12]. An experimentation of Rouhani *et al*. [16] interpreted that plantar pressure parameters in long distance trials can be a strong tool for outcome evaluation of ankle osteoarthritis treatments [16]. In-shoe pressure measurements (figure 4 and figure 5) can quantitatively evaluate the outcome based on pre-post-operative dynamic plantar pressures in hallux vulgus and metatarsalgia [17, 18].

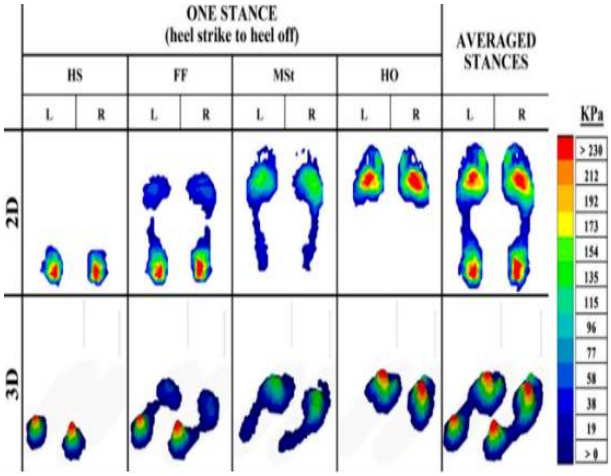

Figure 2 The 2D and 3D representation of in-shoe plantar pressure distribution in a healthy control during the stance phase of the gait cycle, from HS to HO, and the averaged pressure distribution from four stances [17,18]

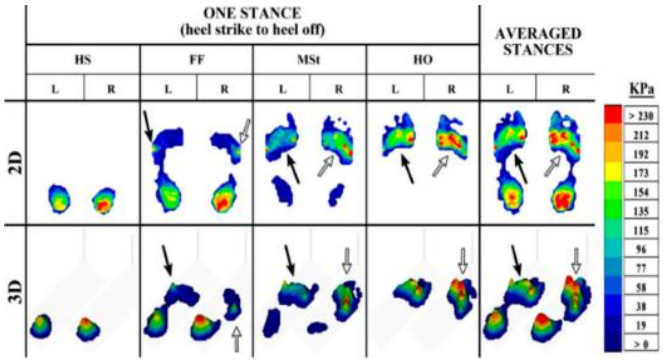

Figure 5 The 2D and 3D representation of an in-shoe plantar pressure distribution resulting from subtalar joint and heel pain in the pathological foot during the stance phase of the gait cycle, from HS to HO, and the averaged pressure distribution from four stances [17, 18].

Plantar pressure assessment also used in variety of foot and ankle related problems such as,

1) Conservative & surgical treatment of lateral ankle instability by Becker, H.P et al. [27, 28, 29]
2) Malleolar, calcaneal, metatarsal fractures. [30, 31, 32]
3) Biomechanical invitro investigations. [31]

B. Sports Biomechanics

Sports like soccer, baseball, basketball, and athletics are demanding situations on plantar pressure on feet [1, 19]. It greatly affects the pressure distribution on the feet because sports involve significant amount of running and jumping which ultimately leads to overloading on foot. Athletes who participate in contact sports like Rugby, soccer or who are involved in high-impact sports like running, dancing and gymnastics are susceptible to first ray forefoot injuries [20]. In sports such as soccer and basketball Repetitive high load on foot can leads to injuries such as metatarsal stress fractures, hallux rigidus, turf toe injury, sand toe injury and sesamoid pathologies [8, 9, 19, 20]. First ray disorders are often treated by nonoperative methods like ice, activity modification, shoe & insole modification and relative rest [20]. ~~Q.~~ Mei et al. [21] have used plantar pressure measurement as a quantitative method to find the biomechanical characteristics of different sports shoes. They had used in-shoe plantar pressure measurement kit with four sensors. Previous articles stated that variety of disorders in athletes are evaluated with the help of plantar pressure distribution of the sportsmen before recommending treatment procedure, whether it is nonoperative or operative treatment [20, 21]. karagounis et al. performed barefoot plantar pressure measurements on ultramarathon athletes before 24 hours, immediate after and after 24 hours of marathon to investigate the overall impact on the plantar pressure distribution and foot loading characteristics. Their results showed significant differences between all the three measurements and concluded that ultramarathon athletes are more susceptible to long lasting effects [22]. The Plantar distribution of this study given in Figure 6.

C. Footwear Design and Injury Prevention

Footwear design plays important role in clinical aspects as well as in injury prevention [3-18, 24, 26] Plantar pressure distribution is one of the main aspects to consider in designing a footwear and insole either for sportsmen, therapeutic, military or for conventional use [2, 23, 24]. Insole in footwear reduces the pressure exerted on the feet by cushioning it, thus protecting feet from impairments related to abnormal/high pressure on feet [2, 23, 25]. The information acquired from plantar pressure measurements are extensively used in footwear research depending on the usage and needs of the wearer.

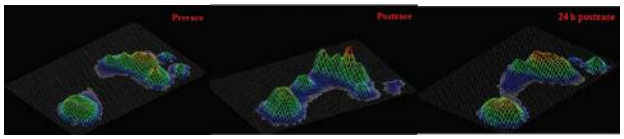

Figure 6. Plantar pressure distribution of a participant (47 years old, body mass index 21.3 kg/m2) prerace, postrace and 24 hours postrace [22].

III. CONCLUSION

Data acquired from plantar pressure measurements are mostly used in evaluating foot impairments associated with musculoskeletal and neurological disorders, foot ulceration, alteration of normal foot function and rehabilitation support system for the same. Other applications include injury prevention in loaded and unloaded gaits, in gait demanding situations like sports and athletics, which require highly customised shoes to protect the lower extremities from injury while playing, thus plantar pressure measurement also plays a huge role in designing foot wear depending upon the usage like whether for hiking, running, or for day-to-day usage. With increasing knowledge of foot function and technical developments, it will be possible to examine and understand the complex information obtained from plantar pressure measurements which will be used for the above applications in a more efficient means.

IV. FUTURE RECOMMENDATIONS:

Most of the studies were constraint to focus on clinical trials of newly designed Orthosis, Insoles, Shoes, Boot mostly on patients but still there is gap between users relate to healthy conditions for the purpose to evaluate the product for more accuracy and precision.

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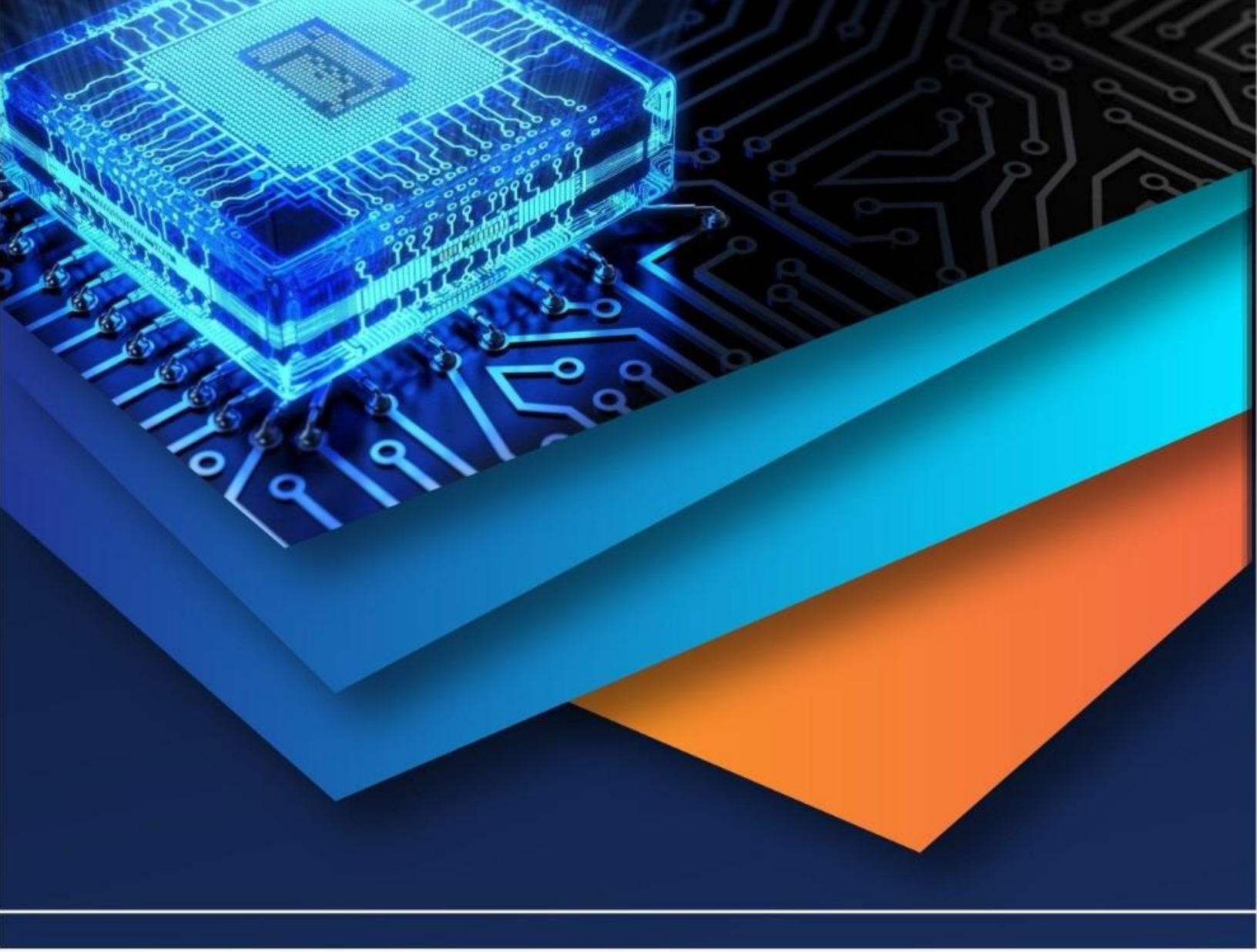

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