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Ergonomic Reviews of Plantar Pressure Tester Development

[1]Butree Kaden, [2]Wutichai Phongmanee and [1]Samchai Jirapatarasilp
[1]Department of Industrial Engineering,
[2]Department of Computer Engineering, Faculty of Engineering,
North-Chiangmai University, Chiangmai, Thailand

Abstract: This study aimed to review several literal researches about ergonomic design in the study and design of tread's pressure tester. Since, researchers aimed to applied ergonomics, embedded system design and computer programming principles to design the tread's pressure tester. Foot is one of the most important organs of human body and it is a fraction that contacts human body to the ground. Several researchers found that adults experience problems with their feet than other parts of the body they consider to be more important to their health. Therefore, researchers aim to applied ergonomics and computer programming principle to design a tread's pressure of human foot to determine pressures occurred in parts of foot that could be useful to evaluate the suitability of collecting shoes design to users.

Key words: Ergonomics, plantar pressure, plantar pressure tester, footwear, applied ergonomics, embedded system

INTRODUCTION

Foot is one of the most important organs of human body and it is a fraction that contacts human body to the ground. It can endure high level of stability and activity and it has several beneficial functions such as extension, compression, bouncing, absorption and friction. Moreover, it can initiate an appropriate elasticity and torsion to human body and also reduce the reaction force from the ground during human is moving.

According to public opinion research on foot health and care findings from a survey of 1,000 American adults in September, 2010 (Research, 2014). The research was studied by the American Podiatric Medical Association (APMA) on attitudes toward foot health and foot care, results found that adults experience problems with their feet than other parts of the body they consider to be more important to their health. Walking and exercise are most likely to be disturbed by foot or ankle pain as well as the ability to be on one's feet. Large majorities of those with regular foot pain are impacted, 72% of Americans expressed foot pain has affected their lifestyle in at least one of these ways.

Many researchers tried to find out how footwear design can lead to different plantar pressures. However, nowadays there are still no obvious guidelines to indicate familiar or unfamiliar footwear (Melvin *et al*., 2014) but normally comfort is always an important reason for choosing footwear of people, greatest people can rapidly identify which type of footwear is comfortable or non-comfortable from wearing during their recreational physical activities (Wiggermann and Keyserling, 2015). As the basic function of human foot is supporting weight by using several parts of human body included bones, joints, muscles and tendons, arches, neurovasculature and surface anatomy (Mundermann *et al*., 2002). From literature (Mundermann *et al*., 2002) arch, volume and length of foot were used to be independent factors for conducting foot cluster analysis and finally five clusters different foot types were identified as follows; flat feet (feet with lowered longitudinal arch), Slender feet (feet with a small volume or narrow widths), Robust feet (feet with a large, wide and high volume) short feet (feet with a short hindfoot and along forefoot proportion) and the last cluster is long feet that is a characteristic of long hind foot and a short forefoot proportion. When the heel is raised the toes are important part to help foot taking up load, since they are incontact with the ground or any footwear for around three-fourths of the walking duration (Mundermann *et al*., 2002; Mauch *et al*., 2008). Moreover, when foot contact to the ground the sole of the foot normally not fully contact to the ground because of the different longitudinal arches and transverse arch (Mundermann *et al*., 2002). Therefore, toes and arches type are other characteristics that cannot be ignored in this research as shown in Fig. 1 and 2.

Corresponding Author: Butree Kaden, Department of Industrial Engineering, Faculty of Engineering, North-Chiangmai University, Chiangmai, Thailand

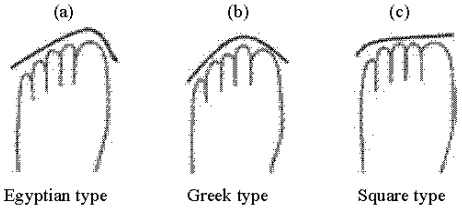

Fig. 1: Three types of foot classified by the relative lengths of digits (Mundermann *et al*., 2002; Mauch *et al*., 2008; Egptian type; Greek type; Square type

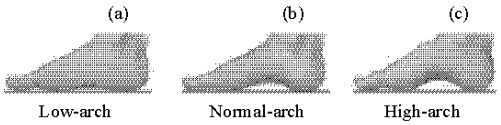

Fig. 2: Three types of foot classified by the relative lengths of digits (Mundermann *et al*., 2002; Mauch *et al*., 2008)

Foot is a complex part of human body and the "Plantar" is a part that contact human to the earth by barefoot or footwear. Foot is a part that moves human to anyplace needed. Moreover, foot has to stand for contact forces and pressures from several parts in different movement of human body. So, researchers considered to find out Ergonomic measurements techniques that possible to assess pressure effort. This research focused on a plantar pressure measurement that has been studied by many researchers all over the world, the literature reviews are categorized in this study to find out a more proper plantar pressure measurement that is the next step of our study.

MATERIALS AND MEHTODS

Researchers searched literatures by using online supplementary data, i.e., Science Direct, Scopus and PubMed by using search terms included: 'ergonomics foot', 'plantar pressure', 'plantar pressure analysis', 'foot pressure', 'plantar discomfort', 'foot anatomy', footwear analyses, 'footwear ergonomics analyses' and 'plantar pressure design'. Studies pertaining to ergonomic ambulance design included in this review according to the following criteria: Original studies from peer reviewed journals in which the subjects were plantar pressure, plantar pressure in ergonomics between 2005 and 2012. The data of plantar pressure information and design techniques subjectively or objectively were compiled and categorized. All paragraphs must be indented. All paragraphs must be justified, i.e., both left-justified and right-justified.

RESULTS AND DISCUSSION

Plantar pressure measurements: Based on searching for literal reviews about plantar pressure measurement. Researchers began with studying about types of measurement that have been studied all over the world. And found plenty of interesting measurement techniques that can be applied for further improvement.

As referred from literature (Hughes *et al*., 1990), 12 subjects involved by walking at preferred and half of the preferred walking speed over a plantar pressure plate that had an active 0.48 m minimum length and 0.32 m maximum width and a resolution of 2.6 sensors per cm^2 and found that this method seemed to be successful for testing various feet type without losing information also in researchers aimed to average step that is representative of the normal gait and tried to study the number of steps required to acclimate a range of footwear types by using plantar pressure data. In literature (Gurney *et al*., 2008) presented a new method to evaluate static pressure during standing by determining the effects of pressure magnitude and foot location on the time until pain begin by using a Time to Pain Onset (TPO) test, the test locations on the foot can be shown in Fig. 3. The findings of this would be benefit to develop the design of shoe inserts and footwear.

Wiggermann and Keyserling (2015), the study aims to present the structure in the mid-foot that can change the shape of the rear foot and forefoot regions and participants can identify the shape changes with different partialities towards definite shapes. In literature (Witana *et al*., 2009) aimed to develop proper changes in shoes, it was necessary to understand the biomechanics of the gait by reviewing the comportment of the lower limbs during the gait cycle, weight transferring and dissemination of plantar pressure. From the study by Lima *et al*. (2015), the results approve that plantar pressure distribution measurements can be used in relative evaluations meanwhile the measures of repeatability are acceptable to choose parameters and foot regions that are generally used in clinical research.

Plantar pressure measuring instruments: Researchers also studied literatures about several tools that can test the plantar pressure as studied from Gurney *et al*. (2008), researchers printed the pressure sensor inserted rubber insole to measure and analyze the plantar pressure that was not the unoriginal mode of pressure sensing of digital capacitors, researchers produce an insole plantar pressure sensor by inserting printed IDCs into an elastic rubber called as PDMS, it changed the dimension of electrodes by outside pressure that caused the difference of

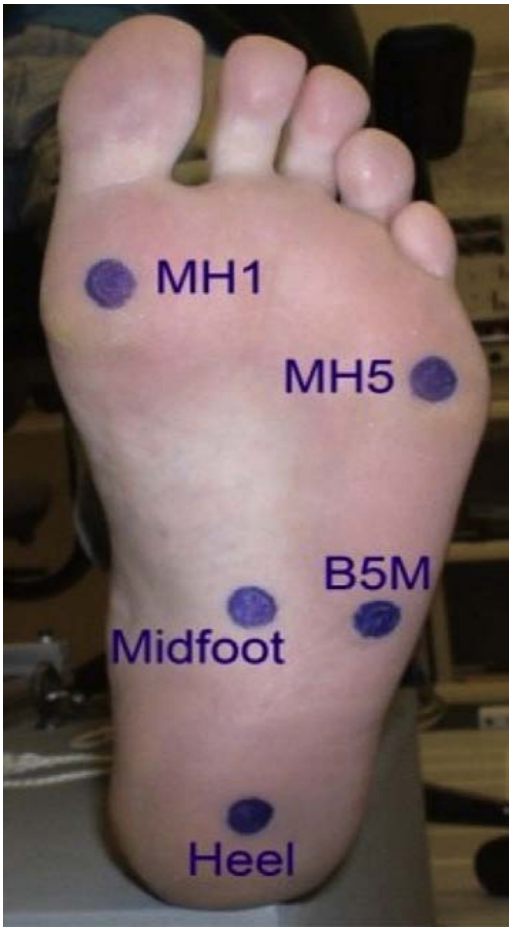

Fig. 3: Test locations on the foot for the TPO test (Keijsers *et al*., 2009)

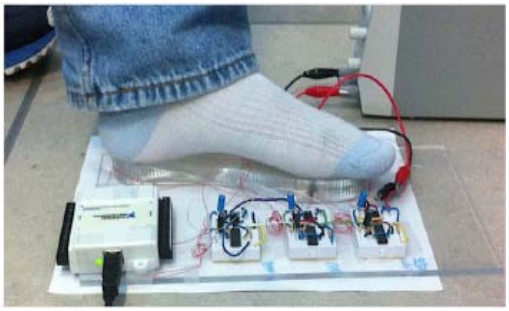

Fig. 4: A setup for measurement in literature (Gurney *et al*., 2008)

capacitance from this study could develop the insole system that response to several foot postures and verified to simulate actual. Walking condition (the instrument is shown in Fig. 4), the flexible capacitive pressure sensor has been established to plantar pressure measuring

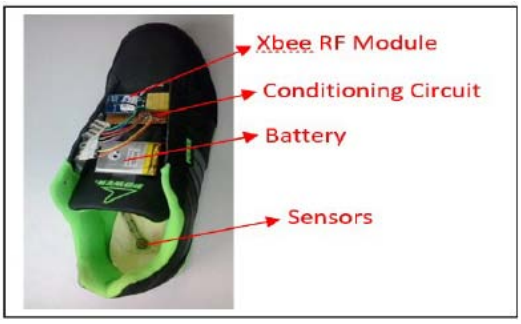

Fig. 5: Measurements and transmission components in literature (Lei *et al*., 2012)

instrument in biomechanical application the material called Poly Di Methyl Siloxane (PDMS) was selected as the material of the dielectric layer with a reason of it is benefit in high dielectric persistent and tunable elasticity (Motha *et al*., 2015).

As studied from literature (Lei *et al*., 2012), researchers required an accurate measurement of the plantar pressure that was an important terms of power source energy concentration, system compact size, part weight and difficulty are considered. Data have been attained with wireless based Xbee RF (Fig. 5) and their results were real time curves that could represent the applied force over the time and can be useful in different analytic uses to improve the upcoming human health care monitoring.

Fiber Bragg Grating (FBG) was another type of sensor used in developing a strain sensing plate for the plantar strain measurement in human foot. In addition, accelerometers had been used to record the movements of center of gravity of the studied subject and the results achieved had been compared to the effect of the postural constancy by using the developed FBG plantar strain sensing plate (Ghazali *et al*., 2015).

In study, Prasad *et al*. (2014), designed and developed a plantar pressure measuring shoe pad with the key features of cost-effectiveness, good working pressure detection sort, portable, wireless data transfer, real-time data analysis and comparative accuracy, initial results showed the insoles calibration and accuracy possibility. Moreovere, the visualization of pressure mapping of the foot sole offers the comprehensive end-user and clinicians that is easy way to understand what the feet experience under different conditions as shown in Fig. 6.

Plantar pressure measurement in footwear development: The proposes of footwear is to provide comfort for wearers and to protect the feet. The design features and

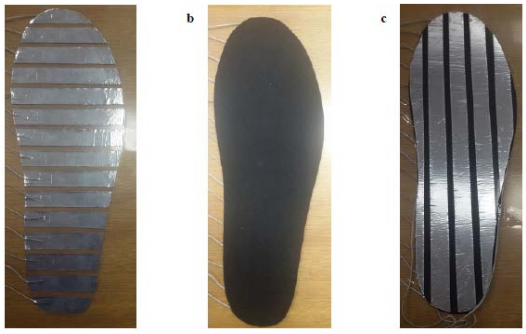

Fig. 6: Different types of insole with electrodes (Prasad *et al*., 2014)

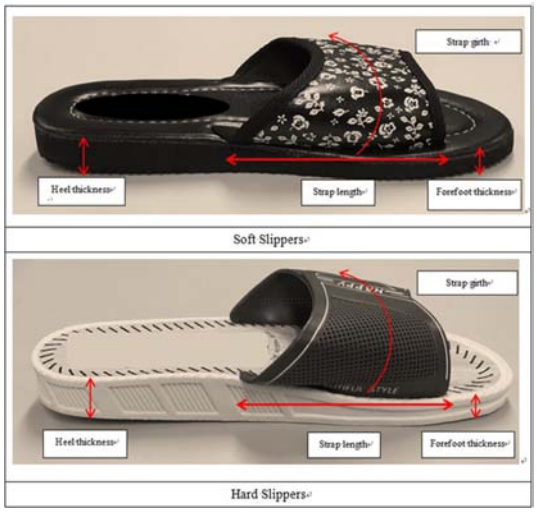

Fig. 7: Two types of open-toe slippers (Tana *et al*., 2015)

fit of the shoe are not only important for changing in the plantar pressure but also a dynamic balance during walking (Tana *et al*., 2015). Several studies in the past on shoe types indicated that the midsole material hardness, the heel height, band and outer sole slip resistance are important variables that distress human balance control and postural stability (Yick *et al*., 2016; Helfand, 2003). The objective of the study (Tana *et al*., 2015) is to evaluate the physical properties of soft slippers and hard slippers and to study the changes in plantar pressure and lower limb muscle activity of older women when wearing these type of slippers (Fig. 7), results showed no significant alteration in the selected muscle activity in all conditions.

In literature (Menant *et al*., 2008), researchers applied biomechanical analysis and the plantar pressure analysis to understand mechanical properties of 2 types of sport shoes in the basic action. Qiua *et al*. (2011) study applied plantar pressure analysis to collect data of 20 healthy participants during 400 min walking by using

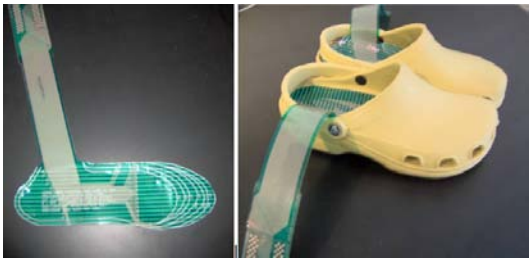

Fig. 8: Pressure mapping sensors in Crocs (Hinz, 2008)

5 footwear designs for females and three for males with two aims studying included; to investigate the number of steps required to create an average step that can represent the normal gait and to inspect the number of steps needed to become accustomed to footwear types. From the study by Melvin *et al*. (2014), researchers aimed to assess the metatarsal head loading in combat boots of the German army shoes with a purpose to prevent the metatarsal stress fractures. Moreover, researchers assessed how cushioning insoles should be made from between EVA foam or neoprene, the results showed that the neoprene insoles lead to in the lowest maximum forces.

A famous footwear company Crocs had applied the study of contact force and pressure measurement on the plantar surface by using flexible force sensors (Fig. 8) during wearing the shoe compared to the most physically comfortable footwear between sneakers of Nike and New Balance and soft soled pull sandals of Merrils and Timberlands. Results of the study are in average total force on plantar surface of feet during walking (lbs) and pressure mapping results also used to indicate forces (Hinz, 2008).

CONCLUSION

With improper footwear design can cause injuries and illnesses and because it is very important to understand not only the foot but also the footwear. With the purpose of reducing injuries and illnesses on foot, the foot and footwear must be matched to avoid the high plantar pressure and friction due to movements (Costello, 2005). Due to several researches studied, researchers learned many interesting information and designing idea to develop a plantar pressure tester. From the beginning idea of research, researchers sympathized with workers in service sector that always have to walk in a long duration during their work. Since, every human absolutely have different foot characteristics, so it is quite impossible that shoes in local market will be fit for everyone even they chose a proper size for them because

there are more complex characteristics needed in shoe designing. Therefore, researchers realized the plantar pressure is one important characteristic for shoe design. So, we aimed to apply ergonomics and embedded system design and computer programming principles to design the plantar pressure tester. After reviewing papers about this, researchers planned to develop a proper plantar pressure tester that is suitable for workers in service sector and would extend the scope of the study to another industry in the future.

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