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Research paper

The Effectiveness of Different Insole Material in Plantar Pressure Reduction : a Pilot Study

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Abstract

Standing is natural human position which is an upright body position against gravity and supported only by feet. It normally caused no health hazard. However, frequent standing together with awkward standing postures may cause discomfort to the foot. This is due to higher value of plantar pressure under the foot and in the long run, its can leads to other health problems such as musculoskeletal disorder. Therefore, insole is believed to have capacity to reduce the plantar pressure under the foot by redistribute the pressure. The use of insole to reduce the plantar pressure has been well document in previous study but very little data reported on assessment among healthy subjects. Hence, the purpose of the study is to evaluate the effects of four different types of insole materials using plantar pressure measurement. The material uses in this study are ethyl vinyl acetate (EVA), Polyurethane (PU), Polyester and Polyurethane with gel (PU gel). Four healthy male volunteer with age mean and SD (24±1.7) years and weight (66±0.82) kg is required to stand in an upright position with minimal movement allowed. The comparison of four insoles with barefoot condition shows that PU insole is the most effective material because it can reduce 16.28% of plantar pressure.

Keywords: *Footwear, balanced standing, discomfort, musculoskeletal disorder, plantar pressure measurement.*

1. Introduction.

Standing is an upright body position against gravity where the body weight is supported by the feet [1]. The anatomy of foot consists of 26 bones, 33 joints with hundred of muscles, tendons and ligaments in order to control the movements of the body especially in lower limbs [2] [3]. Foot physically has three main functions. This includes weight transmission, balance posture and assist in ambulation. More than half of the body weight is supported by heel during barefoot standing condition, while the forefoot which includes five toes and bones called metatarsal support about 28% of the body weight and another 8% of the body weight supported by mid foot[4, 5] It is highly important for person to maintain balance posture in standing to avoid awkward position and in the long run may cause discomfort and other serious health problems [6].

Previous researchers frequently report that musculoskeletal disorder is one of the major health problems occurs in person. It can occur in upper limb involving neck, shoulder and arms and it also occur in lower limb affects from hips to toes [7]. The most common people who are at risk involving person who has awkward standing postures and exposed with fix posture such as standing for more than two hours without break [7] [8].

The main factors that contribute to the skin breakdowns and many other foot problems are excessive plantar pressure. There are available studies in early year of 2000 focusing on evaluating the effects of custom made shoes and therapeutic footwear [9, 10].

Standing on softer surface has always been the solutions to improved blood flow and helps in lowering the discomfort and always associated with wearing suitable shoes [11]. Contrarily, shoes usually are designed for external safety purposes only because it is made from material that are poorly suited for stopping any kind of foot pains [3]. Alternatively, most of the researchers suggest insole as a device to offer comforts and helps in reducing the plantar pressure as it has capacity to reduce pain under the foot by redistribute the pressure occurs under the foot [12]. Besides that, insole is believed to affect plantar pressure distribution by increasing the contact area [13].

These recent years, there are many studies focusing on evaluating the behavior of bones and insole by using finite element analysis (Rizwan and Shuib, 2006, Cheung 2006). This method is quite popular back in 2005 until present time. However, the important to validate the finite element findings using actual experimental work is undeniable. Currently, there are large amount of material that have been used by insole's manufacturer to relieve discomfort to the foot. Insoles made from softer material such as EVA, Poron, PU and Plastazote offer more comfort compare to the hard insole [12, 14]. This phenomenon occurs because soft insole has the capability to distribute the plantar pressure in uniform manner [15]. However, very little data reported on analysis of the insole's effectiveness among healthy people. Therefore, this study will focus on effectiveness of the different insole material among healthy people. The finding of this study will give useful insight about the effect of using different material in insole. This data is beneficial to the podiatrist or physical therapists to prescribe the suitable material to the person.

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2. Materials and Methods.

A total of four male volunteers with age range 22 to 26 years and weight range between 60 to 67kg were provided informed consent before took part in this study. All volunteers were undergraduate student selected randomly from Faculty of Mechanical Engineering, Universiti Teknologi MARA, without any history of disease and foot abnormalities. The demographic data of the volunteers were recorded in **Table 1**.

Table 1: Demographic Data of Four Healthy Male Volunteer.

	Age (years)	Height (m)	Weight (kg)
Volunteer 1	24	1.72	67
Volunteer 2	26	1.73	65
Volunteer 3	25	1.75	66
Volunteer 4	22	1.72	66
Mean (sd)	24(1.7)	1.73(0.01)	66(0.82)

Fig.1: Subjects used in this study

The nature of current study is explorative in order to provide preliminary data; hence the number of sample size is smaller. All of volunteer (Fig.1) need to stand for about thirty minutes continuously in an upright position with minimal movement allowed. There are two approach use to measure the biomechanical measurement in this study; plantar surface of barefoot to the ground (barefoot condition) and plantar surface of foot with the insoles (insole condition). The volunteers are given the sufficient time to familiarize with the measurement system during pilot testing. The purpose of conducting pilot testing is to establish the proper procedure of gait analysis so that any adjustment can be made before actual data collection.

The plantar measurement system used in the study is Foot Scan (FScan) measurement system manufactured by Tekscan. It has thin sensor thickness (0.2mm thickness) and large number of sensor in one layer as illustrated in Figure 2 that will provide more accurate data on plantar pressure distribution when applied to the foot surfaces. The data were recorded for 400 frames in 8 seconds at 50Hz sampling rate. FScan sensor consist of a sole shaped area, together with long handle and can be used as right or left because the software can atomically determine right or left.

The experimental work consisted of two cases studies; barefoot standing condition and insole standing condition. Barefoot standing condition involves plantar surface of barefoot to the ground while insole standing condition involves the ground plantar surface of foot with insole. The volunteers need to stand for thirty minutes for every case study.

Fig.2: The FScan sensor

The insole used in this study (illustrated in Fig.3), is 5mm thickness with four different materials. The materials used in this study are EVA, PU, Polyester, and PU gel. The materials were selected based on popularity demands in the market.

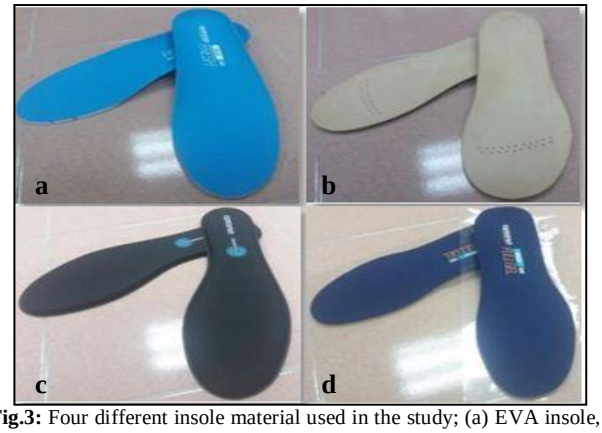


Fig.3: Four different insole material used in the study; (a) EVA insole, (b) PU insole, (c) Polyester insole and (d) PU Gel insole

3. Results and Discussion

All volunteer had a mean age of 24±1.7 years, weight of 66±0.82 kg and height of 1.73±0.01m (presented in Table 1) and has normal body mass index (BMI) of 22.06±0.51. A series of questions were given to the volunteer in order to obtain the feedback about the comfort of the insoles used in this study. All of the volunteers agree that insole made from PU material is softer compared to the other material. The data of mean peak pressure obtained from plantar measurement system is presented in Table 2.

Table 2: Mean Peak Pressure for Both Feet in Different Standing Condition (kPa).

Volunteer		Barefoot	EVA	PU	Polyester	PU Gel
1	Left	86.00	71.29	62.19	66.86	73.57
	Right	91.00	69.86	69.00	77.86	69.00
2	Left	71.00	73.29	69.14	71.71	71.71
	Right	85.00	79.43	78.86	83.00	84.86
3	Left	69.00	82.29	72.29	96.29	80.00
	Right	154.00	101.14	96.43	101.57	96.43
4	Left	99.00	91.86	84.57	96.57	92.00
	Right	89.00	94.43	90.29	93.57	95.43

*The colour column shows the maximum value of mean peak pressure in all volunteers when comparison of all standing condition were made

The lowest minimum of mean peak pressure occurred under PU insole (77.86±10 kPa) while the maximum mean peak pressure occurred under barefoot condition (93±14 kPa). There is huge different for both left and right foot in Volunteer 3 for barefoot condition as the peak pressure of the left foot is 69 kPa and right foot is 154 kPa. This might happen because the anatomy of foot for Volunteer 3 is unilateral. It can be seen in physical changes at the right shoes. The effect of wear and tear at the right shoes is obvious compare to the left shoes. The analysis of maximum, minimum and mean peak pressure is shown in **Table 3.**

Table 3: Minimum, maximum and mean peak pressure for all volunteers

	Barefoot	EVA	PU	Polyester	PU Gel
Minimum	78.00	70.58	65.65	72.36	71.29
Maximum	111.50	93.15	87.43	98.93	93.72
Mean	93.00	82.96	77.86	85.93	82.88

Since the aim of this present study is to evaluate the reduction of the plantar pressure in different insole materials, then the data on both feet (left and right feet) were analysed as one entity.

The highest percentage reduction on mean plantar pressure occur on PU insole when compare with barefoot condition which is

16.28%, PU gel (10.88%), EVA (10.79%) and the minimum reduction is Polyester insole (7.6%). Figure 4 shows the value of mean peak pressure with error bars for all standing conditions.

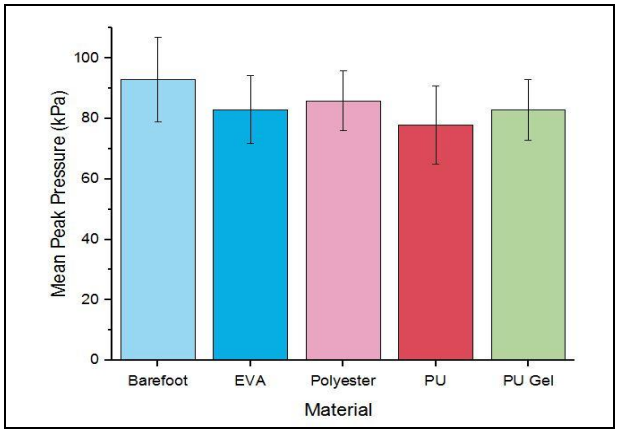


Fig.4: Error bars of mean peak pressure for four insole condition including barefoot condition

The value of contact area for the entire foot when a comparison was made between barefoot condition and EVA insole condition is 8.46 %, followed by Polyester (17.37%), PU gel (19%) and the highest percentage is PU insole (30%). The pressure distribution is indirectly proportional to the contact area across the foot.

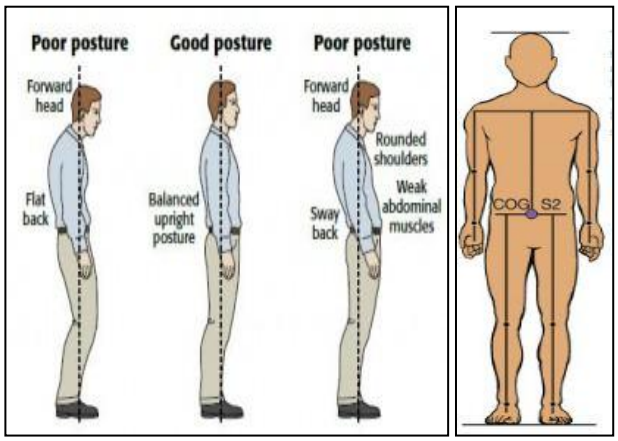
Biomechanical assessment used in this study confirmed that insole have affect the pressure occur under the foot by reducing the pressure distribution. Over the years, there have been many investigations on the use of flat insole with different material either for healthy subjects or people with neuropathic or diabetic problem [16-19]. Insole standing condition offers more comfort to the person as the value of pressure under the foot is lower when compare to the barefoot insole condition. Custom made insole is highly recommended by therapist or orthotics as the best insole to offer better health condition for foot [14, 19, 20]. However, this study used 5mm flat insole with various material. This is because, the flat insole is more suitable for every group of society since it is more practical and economical to use flat insole.

A comparative study between soft and hard insole was rated that soft insole are more significant to increasing the contact area, and helps in redistribute the plantar pressure uniformly [21]. This is due to the behavior of the soft insole material have the shock absorption ability. Besides that, during standing phase, the value of contact area increases over the entire foot during insole standing condition. Fitzgerald, 2013 explained that during stance phase, area of surface contact increase after interventions (after using insole) because larger surface of foot came in contact with ground.

The results obtained from this study shows that PU insole is the best insole material compare to the EVA, PU gel and Polyester as it reduce the peak pressure value by 30% when compared to the barefoot condition. This findings is similar with the previous reports that have been quoted that simple flat Poron can reduce the peak pressure by about 30-39% [18]. Besides that, in previous study between Plastazote, Spenco, Sarbothane, Poron and Viscolas, Poron has rated as the best insole material because of it higher ability to absorbed the pressure under the foot [15, 18]. There is strong evidence that Poron is a group of PU but both Poron and PU has different hardness. The hardness of PU is 15-30 Asker C while Poron has 15-35 Asker C. Researchers suggest that lower Asker index in insole material would give more cushioning properties to the foot loading and effects in more pressure reduction [22].

Besides the behavior of different insole, plantar pressure distribution can be varying in many factors. This factors includes gender, body weight, age and also the standing posture that may effects on foot anatomy [23]. Hence, in this study, the criteria of the volunteers are limited to the same shoe size (7UK size) as researcher tried to obtain consistent findings.

In addition, balance posture is another factor that may affects the plantar distribution. Besides using suitable material for insole, balancing the standing posture (Figure 5(a)) is one of factor that contributes to reducing the plantar distribution. This is because; balance posture is related to the center of gravity. In normal person, the center of gravity is located at the second level of sacral vertebrae. It is important to maintain the center of gravity to the level because it is associated with supporting the body weight to the base of support (feet) [24]. The location of center of gravity (cog) is illustrated in Figure 5(b).



(a) (b)

Fig.5: (a) Poor and good posture for standing; (b) location of center of gravity in normal person

Ludwig, 2017 shows strong relationship of individual posture parameters with the occurrence of lower limbs problems that may leads to the foot problems in a long run. A part from that, the criteria of the volunteers becomes an important factor that affects the data of plantar pressure measurement. Previous study shows significant effects of age on pressure distribution (Ludwig, 2017). Older people tend to have higher pressure distribution compare to the young men. Further research need to take this factor in to consideration when evaluating the plantar pressure distribution. Moreover, the findings of the study should not be limited to the plantar pressure distribution only. Other findings such as contact area and force occurs under the foot could be the important factor to look at. Besides that, the data presented in this study is only on plantar pressure measurement without mechanical evidence on material properties of insole material used. In addition, it only focused on one design factor which is type of material. It is believed that further study involving other design factors such as insole and midsole thickness together with the arch type would be more valuable to the society because by changing the insole or midsole thickness for same material may affects plantar pressure distribution. Moreover, the use of insole with different thicknesses has been shown to be effective on all risk of falling, and postural stability thus affecting the plantar pressure measurement [25] .

4. Conclusion

In summary, it is clear that insole used have the ability to minimize the pressure value under the foot. The most effective insole material is PU because it has minimum value of peak pressure 65.65 [kPa].The maximum value of peak pressure 111.50 [kPa] occurs in barefoot condition. The PU foam is superior compared to other materials in this study because it is effective in reducing the plantar pressure.

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