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Research Article

A Comparison of Foot Insole Materials in Plantar Pressure Relief and Center of Pressure Pattern

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Abstract

Insoles have been widely accepted as a front-line defense to cushion the foot, decrease foot Pressures and reduce tissue destruction associated with repetitive high pressures in the insensate foot. In the recent years, the plantar pressure has widely been accepted as a vital biomechanical parameter to evaluate human walking. The distribution and magnitude of plantar pressure can provide useful information to diagnose the various foot disorders. Plantar pressure measurements during standing, walking or other activities can demonstrate the Patho mechanics of the abnormal foot and yield objective measures to track disease progression1. Areas of increased plantar pressure have been clearly linked to foot pain and discomfort. Increased pressure is also responsible for skin breakdown in the denervated foot such as in Hansen's disease and diabetic neuropathy. Planter pressure was studied with the use of both insoles Silicone gel and MCR (Micro cellular Rubber).

Design: A repeated measure design was followed.

Purpose: The aim of the study was to check the efficiency of both these commonly prescribed insoles (MCR and silicone gel insole) in terms of plantar pressure redistribution and center of pressure pattern with MCR insole and silicone gel insole. The data was managed on an excel spread sheet and was analyzed using the SPSS software PASW (version 17.0). Descriptive statistics (Mean and standard deviation) were computed for each study variable. The outcome variables used for analysis were static planter pressure, dynamic planter pressure and center of pressure. The planter pressure measured for eight areas of the foot, i.e the hallux, 2-5 toe, 1st meta-tarsal, 2-4 meta-tarsal, 5th meta-tarsal, mid-foot, medial heel pressure and lateral heel pressure. A total of 30 subjects were recruited for the study. Out of 30 subjects two were female and 28 were female. A kruskal-wallis test was used to compare the difference in planter pressure (static and dynamic) and center of pressure. The mean age of male subject was 65.53 ± 5.02 years and female was 61.00 ± 1.41 years and for entire

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population the mean age was 65.23 ± 4.99 years. The mean of BMI for male subject was 23.95 ± 2.34 and for female were 22.43 ± 1.50 and for entire population was 22.40 ± 1.52. On the basis of preceding data, we conclude that both the insole MCR and silicone gel insole are effective in reducing planter pressure and realigning the center of pressure pattern. In some major pressure sensitive area of foot (Halux, 1st Metatarsal head etc.) silicone gel insole reducing more pressure than MCR insole. But MCR is a good alternative insole material in reducing the plantar pressure and maintaining the COP pattern.

Keywords: Plantar pressure, COP, MCR insole, Silicone gel insole.

Introduction

In the recent years, the plantar pressure has widely been accepted as a vital biomechanical parameter to evaluate human walking. The distribution and magnitude of plantar pressure can provide useful information to diagnose the various foot disorders. Plantar pressure measurements during standing, walking or other activities can demonstrate the Patho mechanics of the abnormal foot and yield objective measures to track disease progression [1]. Areas of increased plantar pressure have been clearly linked to foot pain and discomfort. Increased pressure is also responsible for skin breakdown in the denervated foot such as in Hansen's disease and diabetic neuropathy. Biomechanical measurements of pressure distribution concentrate on the pressures between the foot plantar surface (sole) and the supporting surface. Various pressure systems are available for the measurements of the pressures inside the shoe or insole and the plantar foot during various activities. Such assessment has proven to be very useful in the diagnosis and management of pressure related foot problems. Attempts to reduce this high plantar pressure have produced a wide variety of shoe insoles which can be inserted into footwear between the shoe sole and the plantar surface of the foot [2]. Utilizing the most effective orthotic material for relief of pressure is important in the prevention of trophic ulceration in the anaesthetic foot as well as in providing relief of pain in such common conditions as metatarsalgia. Past research has shown that clinically painful plantar areas tend to occur at pressures exceeding 254.97 kN/m^2 Insoles have been widely accepted as a front-line defense to cushion the foot, decrease foot Pressures and reduce tissue destruction associated with repetitive high pressures in the insensate foot [3]. One of the major management strategies to reduce elevated plantar pressures in chronic disease is the use of insoles and orthoses [4]. In order to be successful the insole must be able to reduce the elevated plantar pressure to below a threshold level for ulceration. Studies have shown that soft insole materials reduce plantar pressures by conforming to the shape of the foot, thus increasing the contact area of the foot with the ground [5]. The clinical objective is the reduction of plantar pressures, and the mechanical strategy used is the redistribution of load from one region of the foot to another [4]. The foot center of pressure [COP] is a theoretical locus about the foot which is the average location of all the forces acting between the plantar surface of the foot and the ground at any given time during the stance phase (Cavanagh 1978; Rodgers 1988). Understanding center of pressure spatial relationship relative to the location of

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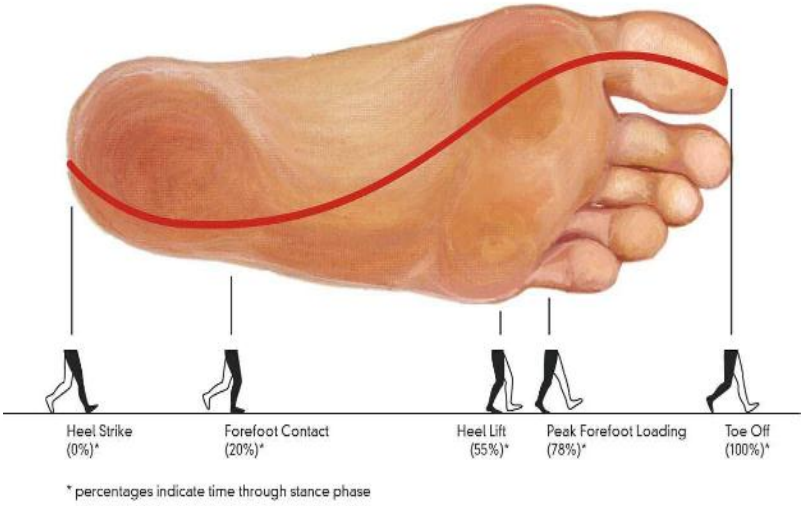
primary joints in normal gait is intuitively helpful in understanding the Patho mechanics of a given patient [6]. When both feet are in contact with the ground, the location of COP under each foot reflects the neutral control of the ankle muscles. COP moves to the anterior with the increased activity of the plantar flexors and it moves laterally with the increase in invertor muscles activity [6].

Figure 1: Gait View.



In previous research COP has been used as a good index to calculate the balance of individuals. COP would be useful in motion evaluation and clinical application [6]. Another study revealed that the COP relations to foot pathology could be used to torques calculation about the joint axis of the foot. Previous studies have also indicated the use of COP to estimate an index to evaluate the function of rehabilitation devices such as foot orthoses during walking [6]. COP trajectory patterns may be correlated with walking speeds and intensity of disorder because in some researches it takes into account [6] previous study prove that planter pressure reduced by MCR insole11and silicone gel insole [7]. The great variety of insoles is available clinically for the measurement of foot ailment. MCR and silicone gel insole are commonly used in our country [8]. So there is strong need to compare the effectiveness of MCR and silicone gel insole. The current study aimed to compare MCR insole and silicone gel insole that could be commonly used for their effectiveness in reducing planter pressure and Realigning of COP pattern.

Operational Definitions

Plantar Pressure

- The pressure which is experienced during static and dynamic posture at plantar surface of foot.
- It was found that the average pressure of a clinically painful plantar area was 398.15k N/m^2. The pressure at different segments of the foot is measured using force platform successive contacts points of the opposite feet.

Center of Pressure

- The center of pressure is defined as the point at which there is no

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moment from all of the applied forces [9]. When the foot is in the stance position, every point of the foot that is in contact with the ground will have some force or pressure applied to it.

- All these forces from different locations can be averaged to arrive at a single force that is equal to the smaller forces acting at a single point. This is called the center of pressure [10].

Micro Cellular Rubber (MCR) Insole

- MCR is a specially processed rubber material, where bubbles of air are introduced into the rubber, creating "micro-cells" that generate a controlled amount of softness and cushioning.
- Even redistribution of pressure.
- Frequently used in insole material for redistribution of pressure.

Silicone Gel Insole

- Medical grade silicones are silicone gel and oil, tested for biocompatibility and are appropriate to be used for medical applications.
- Silicones are inert, synthetic compounds with a variety of forms and uses.
- Frequently used in insole material for redistribution of pressure.

Methods

Sample

1. Sample size- 30.

2. Sample source -

- Indian spinal injury center, vasant kunj.
- From different old age home.

3. Sample technique- Non probability (convenient sampling).

Research Design

Repeated measure design.

Inclusion Criteria

- The age of subjects will range from 60 to 80 years.
- Able to stand and walk independently.
- No leg length discrepancy.
- No lower limb surgery history.
- Able to understand in follow commands.
- Adequate vision hearing; successful use of corrective lenses and/or hearing aid if used.

Exclusion Criteria

- Diabetic Patents.
- Any resent episodes of dizziness
- Any severe and unstable neurological, orthopaedics, surgical, Cardiovascular or medical condition that may affect subject ability to participate in study.
- Subject taking any drug or medication known to adversely affect balance
- Obese patients (BMI>30 kg/m^2) [11].

Instrumentation

Force Platform.

Subject information and consent

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Subject was providing with detailed information regarding purpose and procedure of study. Subsequently they signed consent prior to participation in the study. They were free to withdraw from study at any time.

Figure 2: Force platform.

Figure 3: Weighing machine.

Figure 4: Instrument used in making insoles.

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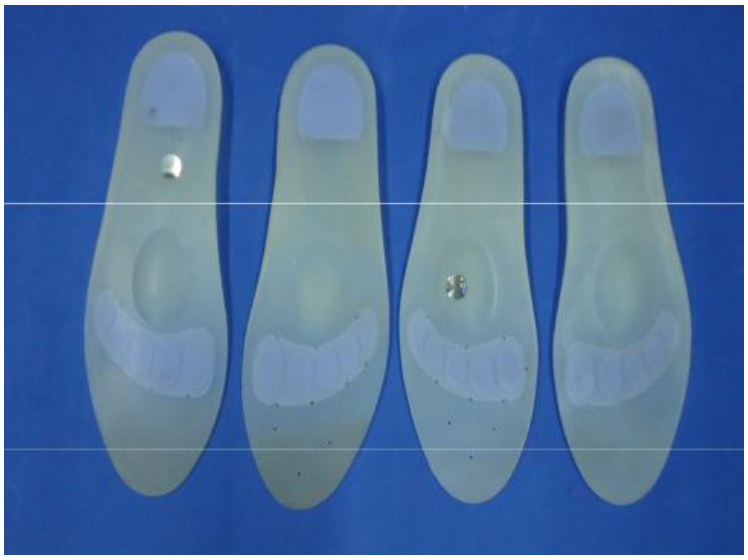
Figure 5: MCR insoles.

Figure 6: Silicone gel insoles.



Protocol

A total number of 30 subjects, who met the inclusion and exclusion criteria, participated in the study and subject were introduced about the procedure and purpose of study followed by signing a consent form then the demographic data of the subjects were taken. Baseline measurements were taken on the force platform immediately before the intervention (pretest). Then MCR insole and silicone gel insole was given for a period of five minute and then again the planter pressure and centre of pressure were measured on the force platform [8].

Procedure

The subjects were invited to percolate in the study. According to the inclusion criteria the subjects were assessed & screened. The details information was given to the subjects about the procedure.

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Subject consenting to participate in the study signed the consent form. The data on the force platform was collected using the 2-step data collection method [12]. The baseline measurements were taken on the force platform for planter pressure (i.e. static and dynamic) and centre of pressure (i.e. dynamic). 3 trials for each measurement were taken [12]. The average of 3 trials gave the baseline measurement. The centre of pressure was quantified using THE MAT-LAB, image processing technique. After taking baseline measurements the subjects were given MCR and Silicone Gel insole for a period of 5 minutes and again 3 trials of measurements (post-test) were taken on the force platform. For planter pressure (i.e. static and dynamic) and centre of pressure (i.e. dynamic). The average of 3 trials was taken to get the post-test measurement [12]. The centre of pressure was quantified using MAT-LAB, image processing technique. During the intervention a researcher was present along with the subjects to ensure safety.

Two-step Protocol

Each subject was positioned 115 cm from the front edge of the force platform. During the feminization period the starting position was modified to ensure that the right foot was placed on the sensor platform with the second step. After striking the platform the subject continued walking. Then the subjects continued walking and returned back such that the left foot was placed on the force platform [13].

COP Quantification

The centre of pressure was quantified using the centre of pressure index. To calculate the centre of pressure index, area medical and lateral to the centre of pressure pattern were calculated using image procession. Image processing was done in three parts; the first two parts were done by specifically GUI based application (The application is developed in the language C# is designed to the work with Microsoft's .Net platform) and part three used MATLAB for calculation of areas only. Part first extraction of the left and the right foot prints (Figure 1). Then lateral and medical part of each foot is extracted along the COP points. Using Brenham line frawing algorithm a connecting lines are draw from top to bottom joining the canter of pressure points. However at the ends, from top first pressure points and last pressure point to bottom a vertical line of division is drawn (Figure 2.). Part second is the pre-processing of each medial and lateral part. The Colored images of each part are converted to greyscale of 256 levels. Thereafter, threshold of gray image is taken up to 96% values. It is followed by Morphological opening that removed all irrelevant points and retains only foot area. Finally, an image negative makes foot pressure region white and rest as black (Figure 4). Part three is post processing for area calculation using MATLAB. Now each part is a white region on black background in the image. All the pre-processed medial and lateral parts of the image have underground through the same process of area calculation. A sample of the script in MATLAB to calculate the area of a region is as follows:

```
E=imread ('01_LEFT_L.jpg');
F= im2bw(E);
G=bwlabel(F,8);
H=regionprops(G);
```


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I=size(H);

Area=0;
For J=1:1

Area=area+H(J).Area;

End

Area

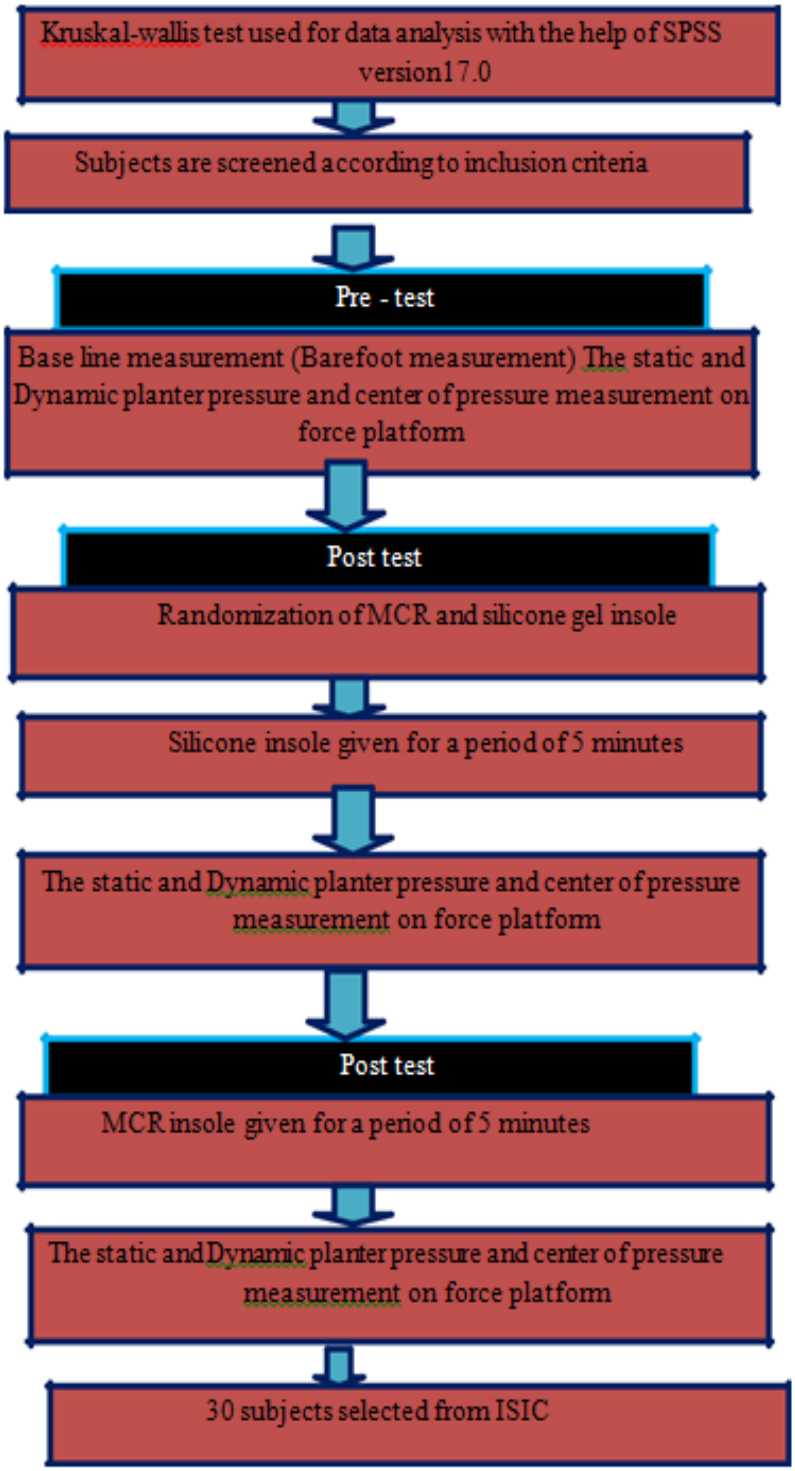

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Fig 7: Subject on force plate performing bare foot static paedobarographic measurements.

Fig 8: Subject on force plate performing static paedobarographic measurements with insole.

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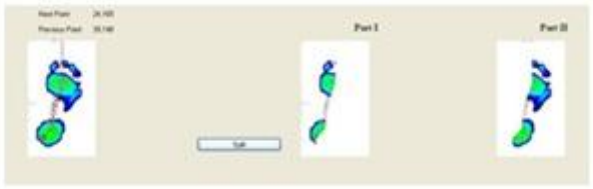
Figure 9: Process of calculating, the area lateral and medial to the cop line, by Mat lab image processing.

1 CROP

2 SPLIT LEFT AND RIGHT FOOT



3 SPLIT ALONG COP

4 COLOR TO GRAY

5 THRESHOLDING

6 CLOSING

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Data Analysis

The data was managed on an excel spread sheet and was analyzed using the SPSS software PASW (version 17.0). Descriptive statistics (Mean and standard deviation) were computed for each study variable. The outcome variables used for analysis were static planter pressure, dynamic planter pressure and center of pressure. The planter pressure measured for eight areas of the foot, i.e the hallux, 2-5 toe, 1st meta-tarsal, 2-4 meta-tarsal, 5th meta-tarsal, mid-foot, medial heel pressure and lateral heel pressure. A kruskal-wallis test was used analyzed the differences between in planter pressure (static and dynamic) and center of pressure with MCR insole and silicone gel insole. Hypothesis was tested at significant Level of $p<0.05$. For the analysis, the separate data of the right and left foot were calculated.

Results

A total of 30 subjects were recruited for the study. Out of 30 subjects two were female and 28 were male. A kruskal-wallis test was used to compare the difference in planter pressure (static and dynamic) and center of pressure. The mean age of male subject was 65.53±5.02 years and female was 61.00±1.41 years and for entire population the mean age was 65.23±4.99 years. The mean of BMI for male subject was 23.95±2.34 and for female were 22.43±1.50 and for entire population was 22.40±1.52.

Change in Static Plantar Pressure

The average change in static plantar pressure due to MCR insole and silicone gel insole are documented. The change in plantar pressure is documented for eight different areas of the foot. The mean decrease in plantar pressure under the hallux region was 35.16% and 34.09% by using MCR and silicone gel insole in left foot respectively and in right foot was 16.53% by MCR insole and 28.85% by silicone gel insole. The 2-5 toe pressure showed 32.94% and 39.53% decrease in plantar pressure in left by using MCR and silicone gel insole respectively and in right foot 5.85% increase in plantar pressure by MCR insole and 22.89% decrease in plantar pressure by silicone gel insole. The mean increase in pressure under 1st metatarsal was found to be 1.94% by MCR insole and 4.71% by silicone gel insole in left foot but decrease in pressure in right foot, 13.25% by MCR insole and 8.41% by silicone gel insole. A 1.56% decrease in pressure by MCR insole in left foot under 2-4 metatarsals and 2.13% increase in pressure by silicone gel insole in same foot but in right foot again 2.31% increase in pressure by silicone gel insole and 2.73% decrease in pressure by MCR insole. The 5th metatarsal pressure showed 3.10% increase in pressure by MCR insole in left foot and 9.46% decrease in pressure by MCR and silicone gel insole respectively. The mid foot pressure increased 35.91% and 30.96% in left foot and 18.11% and 32.42% in right foot by using MCR insole and silicone gel insole respectively. The medial heel pressure showed a decrease of 5.78% in left foot by MCR insole and 2.34% in right foot by silicone gel insole in same foot but in right foot increase in pressure 0.19% by silicone gel insole and decrease in pressure 5.78% by MCR insole. There was a 2.68% decrease in plantar pressure under lateral heel in left foot by MCR insole and 0.78% by silicone gel insole. But in right foot increase in pressure 6.35% by silicone gel insole and 10.35% decrease in pressure by MCR insole.

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Change in Dynamic Plantar Pressure

Under the dynamic conditions the pressure changes due to the MCR insole and silicone gel insole under the different regions of the foot are documented. A 60.81% decrease of pressure was found under the hallux region in left foot by MCR insole and 26.55% by silicone gel insole and in right foot 62.79% and 41.04% decrease in pressure by MCR insole and silicone gel insole respectively. The 2-5 toe regions showed a 52.78% and 10.74% decrease in pressure in left foot by MCR insole and silicone gel insole and in right foot also there is a reduction of pressure 52.96% and 22.31% by MCR and silicone gel insole respectively. Under the 1st metatarsal region a 5.09% decrease in plantar pressure in left foot by MCR insole but 2.89% increase in pressure by silicone gel insole in same foot and in right foot there is a reduction of planter pressure 4.91% and 4.49% by MCR insole and silicone gel insole respectively. The 2-4 metatarsal regions showed increase in pressure 0.43% by silicone gel insole in left foot but decrease in pressure 3.74% by MCR insole in same foot but in right foot only reduction in pressure 2.02% and 2.93% by MCR and silicone gel insole respectively. A 7.48% decrease in pressure by MCR insole in left foot but increase in pressure 7.73% by silicone gel insole and in right foot only increase in pressure 1.50% and 12.03% by MCR and silicone gel insole respectively. There was an 18.83% and 9.77% increase in mid foot pressure by MCR and silicone gel insole respectively and in right foot again there is a increment in pressure 25.28% and 15.67% by MCR insole and silicone gel insole. The medial heel pressure increased in left foot 2.52% and 16.29% by using MCR insole and silicone gel insole respectively and in right foot there is a decrease in pressure 2.48% by MCR insole buto.70% increase in pressure by silicone gel insole in same foot. The lateral heel pressure showed 4.21% decrease in pressure in left foot by MCR insole but 1.62% increase in pressure by silicone gel insole in same foot and in right foot there is only reduction in pressure 9.58% and 4.04% by the using of MCR insole and silicone gel insole respectively.

Shifting of the COP shown by the change in COP index

The average change in COP index with the use of MCR insole and silicone gel insole are documented. A decrease in COP index was found and it is indicating that there is a realignment of COP with the use of MCR insole and silicone gel insole.

Discussion

Our findings revealed that change in both static and dynamic pedobarography evaluation. The Hallux region shows Maximum reduction in pressure with the use of MCR insole (62.79% of right foot in dynamic pedobarographic evaluation). The results shows that during static measurement the medial heel pressure decreased more than the lateral heel pressure but dynamic pedobarographic evaluation revealed that the lateral heel pressure decreased more than the medial heel pressure. This difference in static and dynamic result may explained on the basis of Duckworth et al studies which states that there may be difference in static and dynamic measurement in pedobarographic evaluation [14]. In mid foot region there is more shifting of pressure in static than the dynamic. Shifting of pressure at 1st metatarsal head. This is accordance with the findings of Rinoie and Albert who

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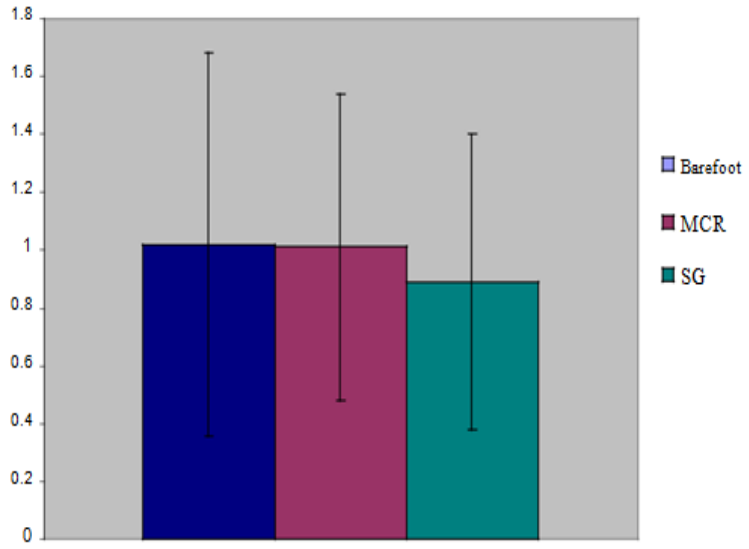
found that the use of custom foot Orthoses in diabetes reduces pressure under the first metatarsal head [5]. There was an increase in 5th metatarsal pressure and 2-5 toe pressure in both static and dynamic evaluation. This increase is more prominent in dynamic measurement than the static measurement. This shows the pressure is shifted from hallux to 2-4 toe pressure by using both the insole; MCR and Silicone gel insole. These findings are supported by previous studies which suggest that the use of foot insert significantly alter the pressure under the different regions of foot [4]. In the current study there is a reduction of planter pressure by the use of both MCR insole and silicone gel insole but in major areas more pressure reduction by silicone gel insole than the MCR insole. One of the major management strategies to reduce elevated plantar pressures in chronic disease is the use of insoles and orthoses [3]. The pressure reduction found by the use of MCR and silicone gel insole was possibly achieved by distributing plantar forces over a larger area of the ground, by increasing the surface contact area of the foot (force/area=pressure) as agreed by Foto and Sanfilippo. The center of pressure pattern also showed that alteration with the use of MCR and silicone gel insole. Kotoh et al stated the center of pressure pattern could be an effective method for quantitatively evaluating the foot orthoses. According to our findings barefoot cop was reduced with silicone gel insole and MCR insole. Thus indicating decrease in center of pressure Index. According to previous researches the higher the center of pressure index, the more unstable the foot and reduction in center of pressure index represents a greater stability in the foot [15]. As our results suggests that the use of MCR insole and silicone gel insole reduces the center of pressure index thus center of pressure pattern shifts laterally in the foot and thus makes the foot more stable. This is also supported by previous study which suggests that the use of Thomas heel shifts the center of pressure pattern laterally.

Figure 10: Comparison of Center of Pressure Index of left foot before intervention (Barefoot) and after intervention (with MCR insole and Silicone gel insole).



Barefoot- Before intervention; MCR- Microcellular rubber insole; SG- Silicone gel insole; COP Index- Center of Pressure Index.

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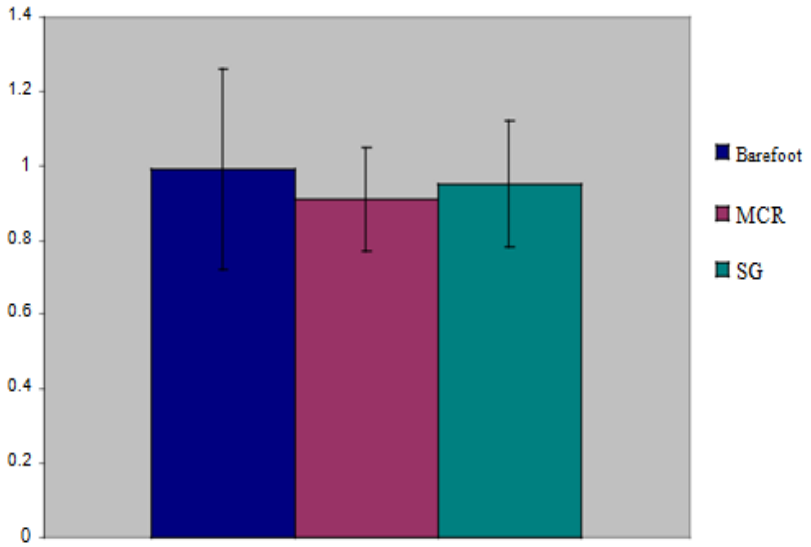
Clinical implication

The results suggest that the analysis gives a quantitative estimation of pressure distribution values with MCR insole and silicone gel insole and which provides information about changes in human posture, foot ailment and knee ailment during walking. Plantar pressure redistribution and realigning of COP may be effective in preventing falls in elderly people. It could be a Cost-effective treatment and preventive measure from the surgical complication. Insoles are very important in restoring foot shape and function.

Figure 11: Comparison of Center of Pressure Index of right foot before intervention (Barefoot) and after intervention (with MCR insole and Silicone gel insole).



Barefoot- Before intervention; MCR- Microcellular rubber insole; SG- Silicone gel insole; COP Index- Center of Pressure Index.

Future research

Future studies would benefit from increasing the subjects with at-risk conditions such as diabetes and rheumatoid arthritis. This would allow the longevity of the insoles effectiveness to be assessed. Studies with larger subject numbers would also allow the power of the study to be improved [16].

Conclusion

We investigated the comparison of foot insole material in planter pressure relief and center of pressure pattern. On the basis of preceding data, we conclude that both the insole MCR and silicone gel insole are effective in reducing planter pressure and realigning the center of pressure pattern. In some major pressure sensitive area of foot (Halux, 1st Metatarsal head etc.) silicone gel insole reducing more pressure than MCR insole. But MCR is a good alternative insole material in reducing the plantar pressure and maintaining the COP pattern.

Limitation of the Study

- A small sample size was the major limitation of the study.
- Mostly male group was included in this study which may limit the

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result to generalize for all population.

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