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AN EXPERIMENTAL INVESTIGATION ON GOLF SHOE DESIGN USING FOOT-PRESSURE DISTRIBUTION DURING THE GOLF SWING

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ABSTRACT

The study aim to analyze the pressure and center-of-pressure (COP) under feet in order to design insoles inside the golf shoes during the golf swing. Four subjects were used for this study. COP and pressure are found to be important factors influencing the stability. For all subjects, overall instability is large in the left feet comparing to the right feet during the golf swing. During the swing phases (impact, follow-through, and end of follow-through), for all subjects, the left insoles should be designed laterally under toes, metatarsal head, midfoot, and heel regions in anterior-posterior direction, while for the right insoles, the design should be in the anterior part (metatarsal head and toe regions) in medial-lateral direction, according to the peak pressures.

Keywords: *Foot-pressure, COP, golf swing*.

1. INTRODUCTION

Golf is a sport enjoyed by different sectors of the public and by different ages which is expanded dramatically [5]. During the golf swing, foot is the only anatomical structure that comes in contact with the ground. Previous studies looked at the kinematic and kinetic aspects of the swing [1, 8]. Carlsoo [2] analyzed the ground reaction forces by using a pressure-sensitive plate during the golf swing in a Swedish player. By using force plates, Cooper, et al [3] examined forces generated by each foot separately to see the shift in the axis of the central load, with the axis itself being determined by Kinematographic techniques. In order to illustrate the kinematic and kinetic description of the feet during the golf swing, Williams and Cavanagh [10] studied the movements and the forces generated by the feet using force plates. The present study has examined the peak pressures and COP under feet during the golf swing to provide information about biomechanics of the feet, and then used this information to suggest design criteria for golf insoles, which would be suitable for the golfers.

2. METHOD

2.1. Subjects and Instrumentation

Four (two men and two women) professional golfers took part in this study (table 1). Two

clubs (driver and 7-iron) were used. The footscan® insole system (RSscan International, Olen, Belgium, 500Hz) was used to measure in-shoe pressures [4] and from the pressures it was calculated COP [6]. The experimental setup is illustrated in figure 1.

Table 1. Subjects characteristics: age, body weight, height, and handicap

Subjects	Age (yrs)	Body weight (kg)	Height (m)	Handicap
Man (1)	22	68	1.76	2 (Low)
Man (2)	31	63	1.73	3 (Low)
Woman (1)	21	71	1.75	8 (Medium)
Woman (2)	21	55	1.65	8 (Medium)

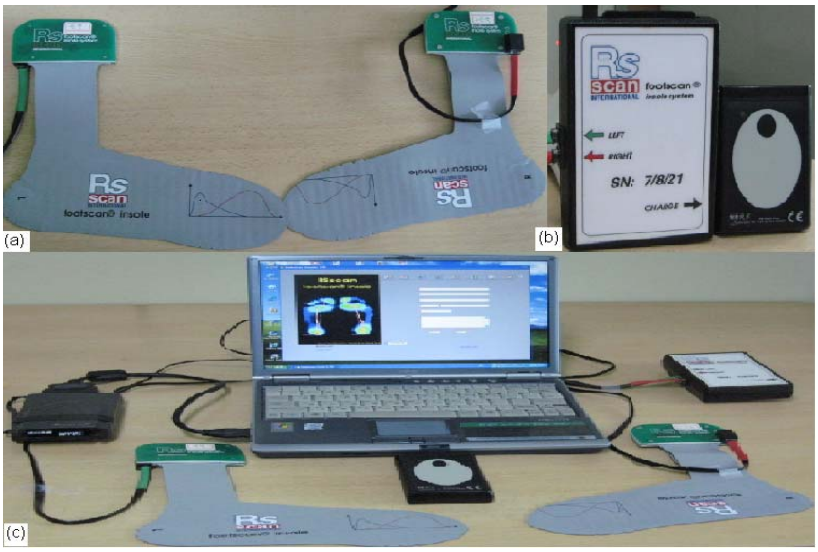

Figure 1. The experimental setup: (a) Rsscan insoles, (b) Data logger with remote control, (c) The footscan® insole system.

2.2. Data Collection and Analysis

By using insole system, data were recoded in a memory card (fig. 2) which enabled dynamic in-shoe pressure measurements including 2s swing (backswing, downswing, impact and following-through) data, for both feet during 8s. In this insole system, landmarks (T1-T5, M1-M5, V1-V4, H1-H4: fig. 2) are located on the pressure images, which are based on the anatomical structures of the foot. The measurements data were analyzed using footscan® insole 2.39 software, in which the subjects body weight was used. It is considered the swing phases (impact: F, follow-through: G, and end of follow-through: H: fig. 4a, 4b, 4c & 4d) to analyze the peak pressures and COP in order to design insoles. In this study, the results are considered only for driver club condition for all subjects. As there is no significant differences in the pressures between the clubs at the time before impact, so the patterns of pressure distribution during the swing are not affected by the clubs.

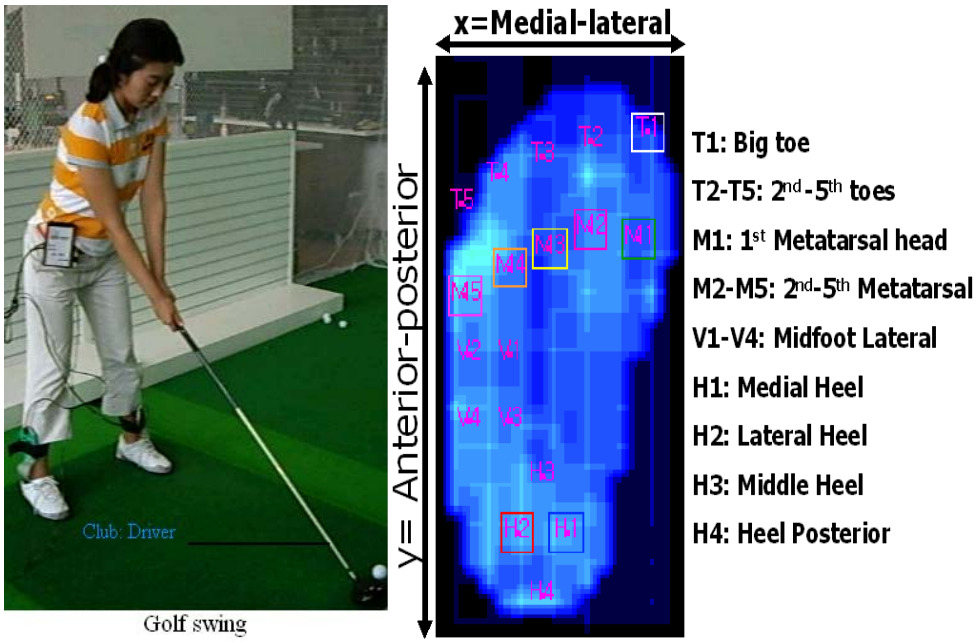

Figure 2. Experimental data collection during the golf swing and the 2D foot pressure screen represents eighteen anatomical landmarks.

3. RESULTS

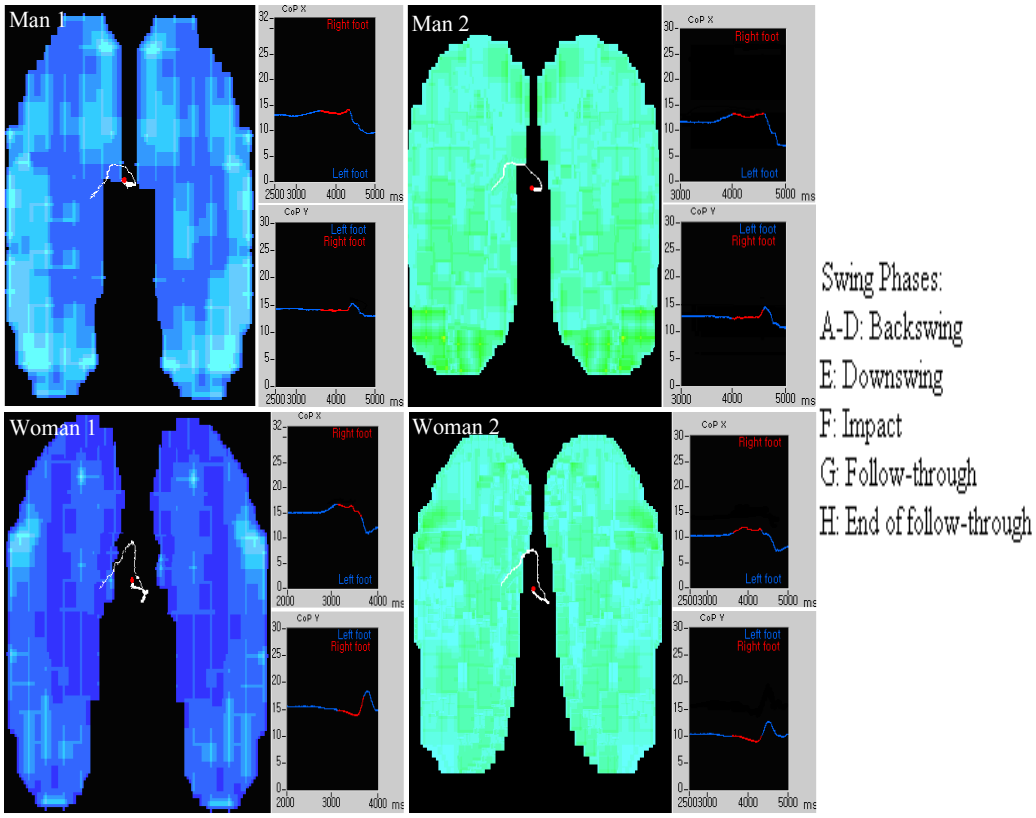

Figure 3. The COP screen (2D views) and COPx (medial-lateral)-time as well as COPy (anterior-posterior)-time curves: (a) for man (1), (b) for man (2), (c) for woman (1), and (d) for woman (2).

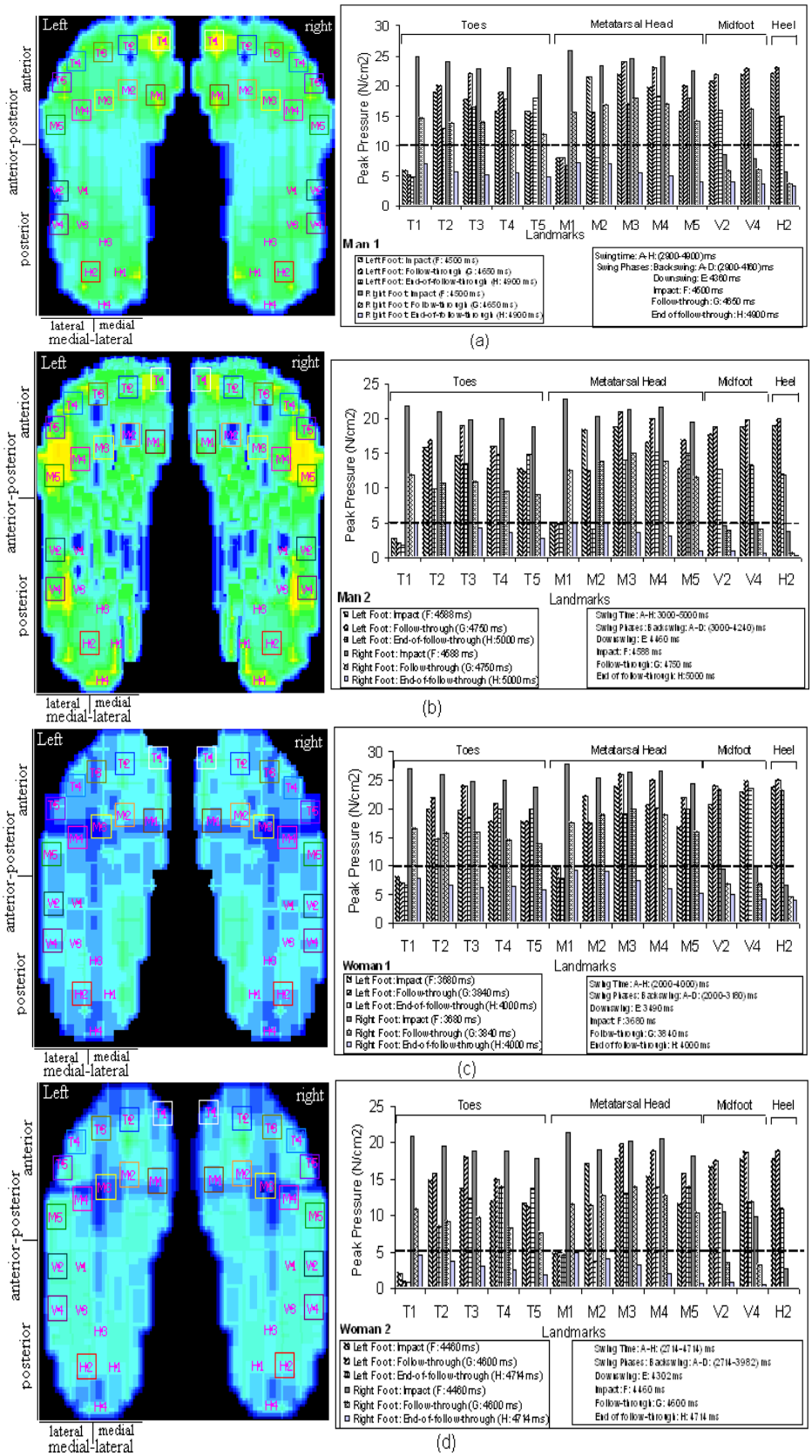

Figure 4. The pressure screen (2D views) and peak pressures under both feet over landmarks: (a) for man (1), (b) for man (2), (c) for woman (1), and (d) for woman (2).

4. DISCUSSIONS

4.1. Peak pressures effect

In the left feet for men (1 &2), during the impact (fig. 4a: 4500 ms & fig. 4b: 4588 ms), the highest pressure is changing in a decreasing order in the regions of the H2 (lateral heel), M3 (3^{rd} metatarsal head), V4 (midfoot lateral, M2 (2^{nd} metatarsal head), V2 (midfoot lateral), M4 (4^{th} metatarsal head), T2-T5 (2^{nd}-5^{th} toes), and M5 (5^{th} metatarsal head). During the follow-through (fig. 4a: 4650 ms & fig. 4b: 4750 ms), the peak pressure is changing in a decreasing order in the regions of the M3 (3rd metatarsal head), M4 (4th metatarsal head), H2 (lateral heel), V4 (midfoot lateral), T3 (3rd toe), V2 (midfoot lateral), M5 (5th metatarsal head), T2 (2nd toe), T4 (4th toe), M2 (2nd metatarsal head), and T5 (5th toe). At the end of follow-through (fig. 4a: 4650 ms & fig. 4b: 4750 ms), the peak pressure is under the M4 (4th metatarsal head), followed by low pressure under the M5 (5th metatarsal head), T5 (5th toe), T4 (4th toe), M3 (3rd metatarsal head), T3 (3rd toe), V4 (midfoot lateral), V2 (midfoot lateral), H2 (lateral heel), and T2 (2nd toe) regions. Oppositely, in the right feet for men (1& 2), during the impact (fig. 4a: 4500 ms & fig. 4b: 4588 ms), the highest pressure is observed under the M1, T1, M4, M3, T2, M2, T4, T3, M5, and T5 respectively. During the follow-through (fig. 4a: 4650 ms & fig. 4b: 4750 ms), the peak pressure is changing in a decreasing order in the regions of the M3, M4, M2, M1, T1, M5, T3, T2, T4 , and T5. At the end of follow-through (fig. 4a: 4650 ms & fig. 4b: 4750 ms), the pressures under the heel (H1-H4), midfoot (V1-V4), metatarsal heads (M1-M5), and toes (T1-T5) are low (less than 10 N/cm2 for man 1 and less than 5 N/cm2 for man 2).

On the other hand, In the left feet for women (1 & 2), during the impact (fig. 4c: 3680 ms & fig. 4d: 4460 ms), the highest pressure is changing in a decreasing order in the regions of the H2, M3, V4, M2, V2, M4, T2-T5, and M5. During the follow-through (fig. 4c: 3840 ms & fig. 4d: 4600 ms), the peak pressure is changing in a decreasing order in the regions of the M3, M4, H2, V4, T3, V2, M5, T2, T4, M2, and T5. At the end of follow-through (fig. 4c: 4000 ms & fig. 4d: 4714 ms), the peak pressure is under the M4, followed by low pressure under the M5, T5, T4, M3, T3, V4, V2, H2, and T2 regions. Oppositely, in the right feet for women (1& 2), during the impact (fig. 4c: 3680 ms & fig. 4d: 4460 ms), the highest pressure is observed under the M1, T1, M4, M3, T2, M2, T4, T3, M5, and T5, respectively. During the follow-through (fig. 4c: 3840 ms & fig. 4d: 4600 ms), the peak pressure is changing in a decreasing order in the regions of the M3, M4, M2, M1, T1, M5, T3, T2, T4, and T5. At the end of follow-through (fig. 4c: 4000 ms & fig. 4d: 4714 ms), the pressures under the heel (H1-H4), midfoot (V1-V4), metatarsal heads (M1-M5), and toes (T1-T5) are below 10 N/cm2 for woman 1 and 5 N/cm2 for woman 2.

4.2. COP effect

COPx (medio-lateral) and COPy (antero-posterior) are used as an indicator of stability [7, 9]. In figure 3, COP is represented as a length in cm. In the graphical representation of the COP (fig. 3a, 3b, 3c & 3d), it is clear that there is a non-cyclic and asymmetric movement between both feet. Besides, for all subjects, COPx (medial-lateral) and COPy (anterior-posterior) were mostly observed in the left foot comparing to the right one. During the time of impact (F: fig. 3a, 3b, 3c & 3d) it has been noticed that, under the right foot, COPx for women was larger than COPx for men, while the COPy for men was larger than the COPy for women. On the other hand, for the left foot case during the follow-through (G-H: fig. 3a, 3b, 3c & 3d), both COPx and COPy for women were much higher than those for men.

4.3. Design Insoles

According to swing phases (impact, follow-through, and end of follow-through), the insoles of the right feet should be designed so that it is provided with a better ability to rock in the regions (M1, M2, M3, M4, and M5) of the metatarsal joints. The toe parts (T1, T2, T3, T4, and T5) should be also considered based on the peak pressures. As a result, only the anterior part of the right foot in the medial-lateral direction can be considered for designing the right feet insoles. On the other hand, the insoles of the left feet should be designed in the lateral regions (H2, V2, V4, M2, M3, M4, M5, T2, T3, T4, and T5) based on the peak pressures. This means that the left feet insoles should be designed in a lateral side in the anterior-posterior direction. This will support the end position of the left feet on its lateral edge to provide wider contact surface. In this connection, Williams and Cavanaugh [10] suggested to rearrangement of the spikes in the outsole by considering the pressures and COP results.

5. CONCLUSION

An asymmetrical design should be considered between the left and the right insoles due to asymmetrical movement of the two feet during the golf swing. The present study shows that during the golf swing, the design for left insole would be more prior than right one. The left insole should be designed under heel, midfoot, metatarsal head, and toe regions laterally, while for the right insole, the design should be in the metatarsal head and toe regions based on the peak pressures. So for the golf shoe, the insoles design should be constructed to reduce the foot pressure and to improve the desired aspects of the swing during the golf swing.

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