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The evaluation of foot pressure and postural structure of national golfers

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ABSTRACT

Objective: The aim of this study was to perform the static and dynamic biomechanical assessment of postural structure and analyze variations of foot pressure in elite golfers.
Methods: A total of 8 golfers (*3 female*, mean age 15.33 ± 0.57 years; mean height 167 ± 3.61 cm and mean weight 59.3 ± 11.71 kg; *5 male*, mean age 17 ± 0.83 years; mean height 177.2 ± 8.61 cm; mean weight 72.8 ± 15.61 kg) from Turkish National Team were participated to this study. Digital Biometry Images Scanning (DBIS) system was used for BioPostural analyses. All participants were applied Modular Electronic Baropodometric test for foot pressure evaluation and Stabilometry for body balance evaluation. Results were analyzed by SPSS 16.0 (SPSS Inc., Chicago, IL, USA) program, using Wilcoxon test.
Results: In static evaluation, there were significant differences in forefoot and rearfoot surface (cm^2) ($p < 0.05$); forefoot and rearfoot load (%) ($p < 0.05$); forefoot and rearfoot weight ratio (%) ($p < 0.05$) and foot angle ($p < 0.05$). In dynamic evaluation, there were significant differences in right and left foot surface and load values ($p < 0.05$). The golfers dominant foot values were higher than non-dominant foot and also the balance parameters were found to be high ($p < 0.05$). The BPI Static mean value of the golfers were 7 points. The BPI Dynamic mean value of the golfers were 29 points. Also the golfers' Stabilometric (Balance) Evaluation results were 20 points, whereas the norm values ranged from 0 to 10.
Conclusion: Our results suggest that static and dynamic postural structure parameters are very important for performances and injuries of the golfers. It is believed that these differences were due to the weight transfer applied especially in the swing motion at the moment of impact.
Level of Evidence: Level IV, Diagnostic Study.

Posture is the position that defines the relationship of the body parts to each other and to the body's gravity line. Static posture of the body may refer to the standing position, whereas dynamic posture has successive sequences of movements.[1] Proper posture is achieved by using minimum energy while keeping the joints under the least stress, and without proper pressure of the feet positions, unnecessary energy consumption occurs during movement. Postural deviations have been linked to a series of different kinds of pain and dysfunction. Since the human foot is the basis of support and propulsion for gait, baropodometric analysis which assesses the dysfunctions of the feet may be valuable in terms of postural assessment.[2]

Golf is an outdoor sport enjoyed by people of all ages. It requires walking long distances and standing up for a long time.[3] The foot care and health are very important factors for the golfer's performance. Ankle and foot injuries may result from long standing and walking.[4] Golf is a highly individualized sport and golf skill development is largely driven by the instructors' experiences.[5] Weight transfer in the golf swing is a coaching term used to describe the movement of weight between the feet during the swing. A typical sequence of weight transfer was described by Leadbetter as evenly balanced between the feet at address (start of backswing) moving towards the back foot during backswing.[6] Just before the start of downswing, the weight begins to move towards the front foot, rapidly in the early downswing phase continuing through to the front foot at ball contact and at follow-through.[7] Highly skilled

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golfers exhibit greater center of pressure excursion than less-skilled golfers. However, the mechanism in which golfers dynamically distribute the forces across the back- and target-feet is less clear.[8] In Lindsay and Vandervoort's study, 54% of the professional golfers have complained of chronic ailments that prevented them from playing golf for five weeks on average every year.[9] Most of these injuries usually take six months to resolve.[10]

The Foot Posture Index (FPI) is a quick and simple clinical tool which allows a multiple-segment and multiple-plane evaluation of the foot posture while offering some advantages over the existing clinical measures.[11] A baropodometer has the potential to provide excellent research in the postural field and related areas.[2]

The main purpose of this study was to investigate the static and dynamic biomechanical postural structure and foot pressure variations among elite golfers. As a hypothesis of this study, there were some imbalances and differences in the static and dynamic foot pressure and postural structures of golfers.

Patients and methods

Eight golfers from the Turkish National Team were included in this study voluntarily (Table 1). The golfers had not experienced any lower extremity injuries previously.

The study was conducted in accordance with the Declaration of Helsinki. Before the study, the subjects were informed about the research including its potential risks and benefits. Written consents of all participants were obtained.

Data collection was done at Pedissence Diagnostic and Therapeutic Technology Center, Istanbul. All participants were asked to refrain from alcohol, caffeine and ergogenic aids the day before the test. No warm-up time for the participants was given.

The Digital Biometry Images Scanning (DBIS) system was used for biopostural analyses. All participants had the modular electronic baropodometric test for foot pressure evaluation and stabilometry for body balance evaluation. The barosensitive platform was 80 cm long and 40 cm wide.

The golfers were required to stand on the pressure plate and remain in a natural and relaxed position for 5–10 s for orthostatic assessment, expressed as a mean calculation of the golfers' oscillations (Fig. 1). Subsequently, the golfers were requested to walk along the walkway for the dynamic test. The data between the moment the golfers made contact with the walkway and the moment they left it was acquired (Fig. 2). This examination was repeated three times in order to identify any gait or balance disorders. The evaluation of each gait cycle involved the monitoring of the central pressure points of each foot during the roll of the plantar from the rearfoot until the forefoot was released; surface and load numerical values were captured.

The following parameters were investigated during the static posture; support surface areas of both feet, loading pressure between the rearfoot and forefoot and the pressure exerted upon the medial and lateral portions of each foot. Dynamic postures were evaluated taking the support surface areas of both feet and the pressure exerted on the ground into account. Static and dynamic

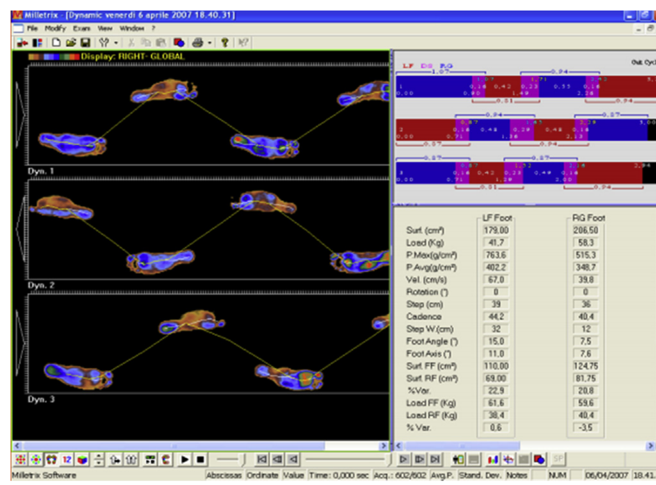

Fig. 2. Dynamic evaluation of the feet.

Table 1
Demographic data of elite golfers.

	Age (years)	Height (cm)	Weight (kg)	Shoe size	Foot base space (cm^2)
Female (n = 3)	15.33 ± 0.57	167 ± 3.61	59.3 ± 11.71	39 ± 1.73	1.43 ± 22.36
Male (n = 5)	17 ± 0.83	177.2 ± 8.61	72.8 ± 15.61	43 ± 1.89	1.89 ± 49.4

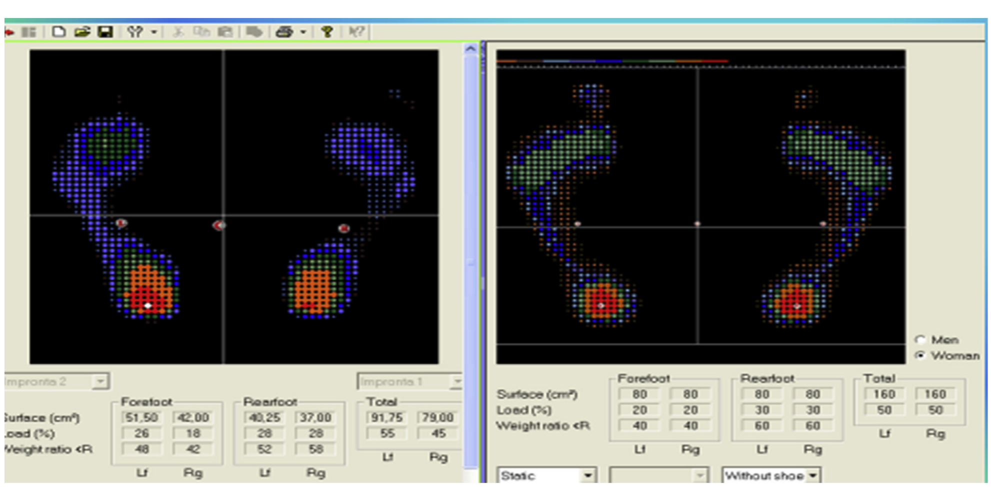

Fig. 1. Orthostatic examination of the feet.

postural evaluations were performed in association with the foot pressure variables and the biopostural index (BPI) was calculated.

The variables data from the electronic baropodometric test were statistically analyzed using the SPSS v.16.0 (SPSS Inc., Chicago, IL, USA) software. The results were presented as mean ± SD. The differences between the right and left foot pressure were analyzed using the Wilcoxon test. Statistical significance was set at $p < 0.05$. The initial power analysis indicated that seven participants were required to reach a statistical power of 80%.

Results

In the evaluation of the static standing position, significant differences were detected in the forefoot and rearfoot surface (cm^2), forefoot and rearfoot load (%), forefoot and rearfoot weight ratio (%) and foot angles between the left and right feet ($p < 0.05$) (Table 2).

In the dynamic evaluation, there were significant differences in the right and left foot surface and load values between the left and right feet ($p = 0.024$ and $p = 0.031$ in females and $p = 0.04$ and $p = 0.042$ in males, respectively) (Table 3).

The mean static BPI results are shown in Table 4. According to the norm of body posture static index, the average value must be between 0 and 10 points. The mean static BPI of the golfers was 7 points.

The mean dynamic BPI results are shown in Table 5. According to the norm of body posture dynamic index, the average value must be between 0 and 20 points. The mean dynamic BPI of the golfers was 29 points.

The mean stabilometric (balance) evaluation score of the golfers was 20 points, whereas the normal values ranged from 0 to 10 (Table 6).

Table 2
Static baropodometric test results.

Forefoot	Left		Right	
	Female	Male	Female	Male
Surface (cm^2)	32.08	46.05	40.4	48.7
Load (kg)	16.7	21.9	22.7	25.5
Weight ratio (Forefoot/Rearfoot)	37.6	47.8	40.2	47.7
Rearfoot				
Surface (cm^2)	34	44.6	37	49.6
Load (kg)	26.8	24.5	33.8	27.9
Weight ratio (Forefoot/Rearfoot)	61.4	52.1	63	52.2
Total				
Surface (cm^2)	66.0	46.0	77.5	78.3
Load (kg)	25.6	21.9	33.6	39.2
Foot angle (°)	9.5	12.5	11	15
Foot axis (°)	13.8	15.3	11.6	13.4

Table 3
Dynamic baropodometric test results.

	Left		Right	
	Female	Male	Female	Male
Acq N°	18.3	15	17.3	16.7
Time (s)	0.776	0.710	0.730	0.700
Surface (cm^2)	87.2*	118*	73.7*	116*
Load (kg)	54.4*	50.2*	45.5*	49.4*
P. Max (g/cm^2)	1000	1008	1678	951
P. Avg (g/cm^2)	686	616	995	630
Velocity (cm/s)	83.7	101	108	109
Step (cm)	58	61	57.6	62.7
Cadence	52.4	48.5	58.1	65.0
Step width (cm)	13.1	14.5	14.2	8.5
Foot angle (°)	11.8	17.7	17.3	17.7
Foot angle axis (°)	7.8	10.6	7.7	10.6
Surface FF (cm^2)	48.1	59.9	38.2	65.7
Load FF (kg)	53.1	51.1	54.9	53.4
Surface RF (cm^2)	39	58.1	35.5	50.6
Load RF (kg)	44.9	47.7	42.2	45.1

FF: forefoot; RF: rearfoot.
*$p < 0.05$.

Table 4
Mean static biopostural index results.

	BPI
CoP geometric position	0
Load bipedal variation	0
Rearfoot/Forefoot load variation (L-R)	0–3
CoP angle	3
Foot angle axis (L-R)	0–0
PMP localization (L-R)	0–1
Surface variation	0
Total BPI	7

BPI: biopostural index, CoP: center of pressure, L-R: left-right; PMP: point of maximum pressure.

Table 5
Mean dynamic biopostural index results.

	BPI
Bipedal load mean variation	2
Rearfoot/Forefoot load variation	0–0
Mean foot angle axis (L-R)	0–2
Mean PMP localization (L-R)	2–3
Mean length of the results of force line (L-R)	1–2
Half Step/Step Line Length	1–2
SD Gait cycle (L–R)	0–1
SD Gait cycle double support (L-R)	3–1
Inversion of load between static and dynamic (L-R)	1
Load inversion R/F between static and dynamic (L-R)	0–2
Surface foot variation between static and dynamic (L-R)	3–3
Total BPI	29

BPI: biopostural index, L-R: left-right; PMP: point of maximum pressure, R/F: rear/fore, SD: standard deviation.

Discussion

In this research, the peak pressure, the mean maximal pressure and the time pressure integral of various parts of the sole in professional golf players were examined for the left and right feet. According to the results of the static evaluation, there were significant differences in the forefoot and rearfoot surface (cm^2), forefoot and rearfoot load (%), forefoot and rearfoot weight ratio (%) and foot angles ($p < 0.05$) between the left and right feet. The values for both the dominant forefoot and rearfoot were higher than the non-dominant values. Similar to the static evaluation, significant differences in left and right foot surface and load values were detected in dynamic evaluation; the values of the dominant foot were higher ($p < 0.05$). Foot pathologies and anatomic deformities can negatively influence the foot function, consequently

Table 6
Mean stabilometric (balance) evaluation results.

	BPI
Romberg index	3
Sway axis inclination (OE-CE)	3–3
Mean velocity (OE-CE)	2–0
L–L velocity correlation	2
A-P velocity correlation	1
L–L/A-P velocity correlation (OE-CE)	3–3
Sway direction variations	0
Total BPI	20

A-P: anterior-posterior, BPI: biopostural index, CE: closed eyes, L–L: lateral–lateral; OE: open eyes.

impairing gait during daily activity and severely impacting the quality of life. These pathologies and deformities are often painful and associated with high or abnormal plantar pressure, which can result in uneven pressure distribution between the two feet.[12] Some studies have demonstrated no significant differences in postural test measurements between the left and right limbs[13] or the dominant and non-dominant limbs of healthy subjects in single-leg stance.[14] Sporting history and limb dominance do not influence knee-joint proprioception when tested in an open kinetic chain using passive repositioning.[15] Walking long distances, walking in a hilly terrain and very short resting periods may cause painful foot syndromes in golfers. Contrary to the literature, it was considered that the pressure applied by the two feet were different as the subjects were professional golfers and also because of the way they positioned their bodies during the weight transfer due to the specific swinging techniques. The study showed that an improper golf swing in players with a moderate or high handicap may contribute to golf-related injuries. The more skilled golfers achieved better coordination of motion.[16] For golf performance, it is quite important to have faster clubhead velocities and lower launch angles of the golf ball, related to reduced lateral bending of the lower trunk.[17]

Postural stability is an important factor in injury prevention, performance optimization and tactical training.[18] The distance between the center points of the two heels give the step width, which should be ideally between 5 and 10 cm. This distance increases when the knee joint is more than 9° of valgus, or when there is abductor/adductor muscle weakness of the hip joint. Pathologic conditions are observed in cases with a step width below 5 cm. Another feature of the walking cycle is the external rotation angle of the foot, which is seen with the axial rotations of the femur and tibia in the transverse planes and is normally between 5° and 7°. In this study, the mean static BPI was 7 points which falls within normal limits. On the contrary, the mean dynamic BPI was 29 points which was higher than the normal values. The parameters of dynamic assessment therefore seem to be affected by age, training or a combination of both.[19] Sporting history has a direction-specific impact on dynamic postural control.[15] Meardon et al indicated that dynamic postural control, particularly related to the attenuation of vertical forces, may be impaired in runners with a history of prior injury when compared to healthy runners.[20] Another research by Cherati et al found that there was no significant association between the FPI and the occurrence of ankle sprain.[21] Ball and Best[22] indicated that most of the golfers (96%) used the same swing style for three different clubs. In their study, golfers that used the reverse swing positioned their center of pressure nearer to their toes at ball contact compared to golfers that used the front foot swing. Additionally, Zhang and Shan suggested to improve the consistency of the swing execution so that golfers can achieve higher success rates in their golf driver swings.[23]

Another parameter evaluated in the study was the stability (balance) of the golfers. Studies have shown that golfers reported significantly higher balance confidence score ratios.[24] Sport-specific movements along with characteristic plantar pressure distribution and muscle fatigue result in an increasing postural sway, and therefore lead to a decrease in balance control.[19] The stabilometric values of the golfers were also 20 points and thus above the normal values. Having high dynamic posture values of golfers will cause negativities especially in balance and stroke performance. However, the research mentioned that the effects of fitness and neuromuscular performance on balance are more than those of biomechanical factors such as foot posture.[25]

A limitation of this study was the small sample size since the subjects with musculoskeletal injuries, a history of surgery or neurological conditions were excluded. Therefore, the findings can only be generalized to a population of healthy, young national golfers between the ages of 15 and 18.

In conclusion, this study indicates that static and dynamic postural values in golfers who require a long walking movement are very important for performance and injuries. The golfers' dominant foot values were higher than the non-dominant foot in addition to the balance parameters. We believe that these differences were due to the weight transfer applied especially in the swing motion at the moment of impact.

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