FORCE GENERATION AT THE GOLF SHOE SOLE TO GRASS TURF INTERFACE OCCURRING WITH ALTERNATIVE SPIKE DESIGNS.

Paul Worsfold[†], Neal Smith and Rosemary Dyson

University of Chichester, Chichester, West Sussex, UK.
[†]Present address: University of Chester, Chester, Cheshire, UK.

Forces were measured at the golf shoe sole to natural turf interface while eight low handicap golfers performed distance shots with a driver. Two types of golf shoe were worn. Forces were analysed using two Kistler force platforms and measures of maximum vertical force and the amount of force generated in the vertical, anterior and posterior, and medial-lateral planes showed similar values for the two shoes but with forces at the front foot greater than those for the back foot. At the back foot the torque (Tz) range generated was notably significantly greater at a mean 17.58 Nm for the shoe design based on 7 spikes than for the shoe design based on 6 spikes for which a mean Tz of 14.82 Nm was recorded (P<0.05). The rotational Tz force was similar at 42 Nm approximately for both the 7 and 6 spike shoe designs at the front foot.

KEY WORDS: golf, force, shoe, spike, torque, turf.

INTRODUCTION. Increased golf course usage arising from the game's popularity has resulted in concerns about damage to the turf by traditional metal spike golf shoes, and subsequently the latter have been banned from many courses. Manufacturers have developed new shoe designs based upon the inclusion of plastic alternative spikes. Evaluation of such shoes has been reported in terms of force generation at the sole-artificial grass (astroturf) interface, but not at the natural grass interface as highlighted by Williams and Sih (1998). This research, using a natural grass turf interface and outdoors testing environment, investigated the forces generated when wearing a golf shoe with 7 alternative spikes and a shoe designed with only 6 alternative spikes.

METHOD. Eight experienced golfers (Mass 76.1 ±8.8 Kg) with a low handicap (range 0-7) volunteered and provided informed written consent. Two different golf shoe designs were worn during the testing procedure. Both types of shoe had an identical full grain leather upper, full grain leather lining and an ethylene vinyl acetate (EVA) midsole. However, one of the shoes had an Adidas sole plate fitted with seven Fast Twist™ alternative spikes as shown in figure 1, and the other had an alternative spike sole plate based upon an Adidas six spike design as shown in figure 2. It was noteworthy that the 7 alternative spike shoe's sole bed incorporated lateral sole mouldings in the same format as utilised by the manufacturer in the sole plate design of their traditional seven metal spike golf shoe. The alternatively 6-spike shoe sole incorporated small sole mouldings (approximately 10mm long) and had only six alternative design spikes.

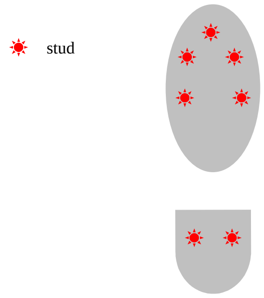

Figure 1. "Stripe Tournament" golf shoe diagram with seven Fast Twist™ alternative Spikes

Figure 2. "Tour Traction Competition" golf shoe with six Fast Twist™ alternative spikes.

Participants were allowed time to accustom themselves to the two types of shoe and the testing environment. Golfers completed 5 shots from a tee mat surface with their own driver using new Titleist DT white golf balls. Golfers adopted their normal stance for driving shots with each foot on a grass turf covered force platform. The turf was attached to a clay covered rigid plate, which was screwed onto the top of the force platform (Janaway and Dyson, 2000). The force platform horizontal plane offset was 35 mm to allow for the depth of the turf-covered plate.
Foot action forces were measured through the two force platforms as shown in figure 3. The clockwise rotation denotes a positive force moment while the clockwise rotation denotes a negative ground reaction force moment.

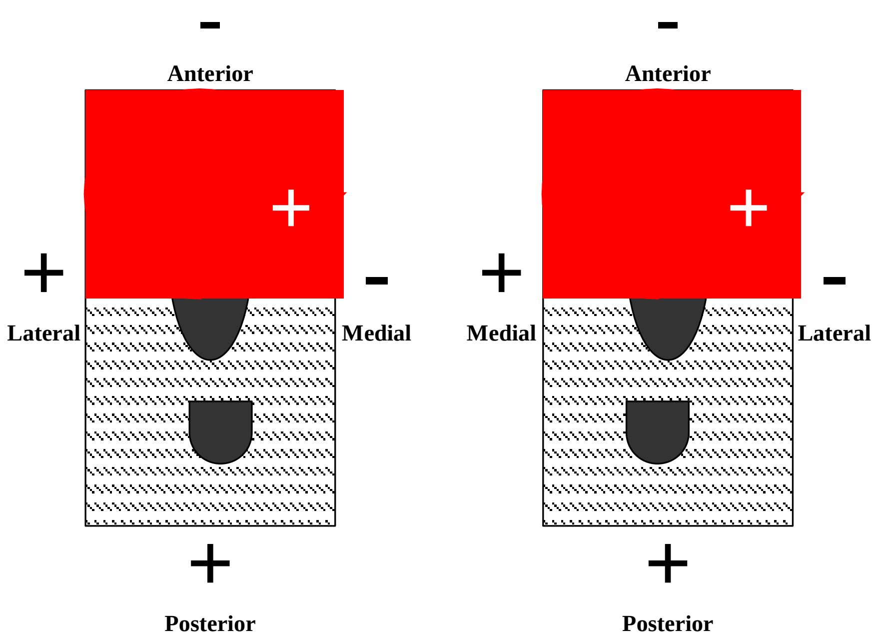

Figure 3. Notations used during analysis of vertical (Fz), anterior-posterior (Fy) and medial-lateral (Fx) forces and rotational forces.

Data from the two 9851B Kistler force platforms was passed to a Kistler 9865 amplifier and a 12-bit analogue to digital converter. Data was collected using Kistler 3.1 Bioware software with sampling at 1000Hz. Data was stored to the personal computer hard disk for subsequent analysis. Peak force and the range of force recorded during the movement at the shoe sole-turf interface was determined in the vertical and horizontal planes for each foot, and the rotational torque of the centre of pressure. For each subject, data were normalised to body weight. A synchronised 200Hz Peak Performance camera captured the golfer's driving movement and allowed the club and ball impact to be identified in relation to the foot force analysis. One-way analysis of variance with repeated measures was used to analyse any differences in the forces generated when the different shoes were worn.

RESULTS. The low handicap players hit 89% of their shots straight. Table 1 indicated that the forces applied at the front foot were consistently greater for the maximum vertical forces, and for all vertical and horizontal action force ranges, illustrating the higher traction requirements of the front foot shoe. The Fz maximum force and ranges of the vertical Fz range were similar for both the 7 and 6 spike shoes. However the Fy anterior-posterior range was greater for the 7 spike shoe than for the six spike shoe design ($P<0.05$).

Table 1. Action forces (mean ± SE) for the low handicap right-handed golfers using a driver

Foot	Shoe	Fz Max (BW)	Fz Range (BW)	Fx Range (BW)	Fy Range (BW)
Front (left)	7 spike	0.812 ±0.036	0.810 ±0.035	0.254 ±0.015	0.297 ±0.012
	6 spike	0.797 ±0.032	0.794 ±0.031	0.248 ±0.016	0.264 ±0.012
Back (right)	7 spike	0.488 ±0.028	0.328 ±0.032	0.202 ±0.018	0.154 ±0.006
	6 spike	0.501 ±0.022	0.356 ±0.032	0.188 ±0.015	0.136 ±0.009

Golf requires large rotary movements throughout the body during the golf swing process. To gain an accurate understanding of the shoe ground interaction during the swing, rotational forces occurring at the shoe ground interface were identified by analysis of the torque Tz (Free moment about the centre of pressure) as shown in figure 4.

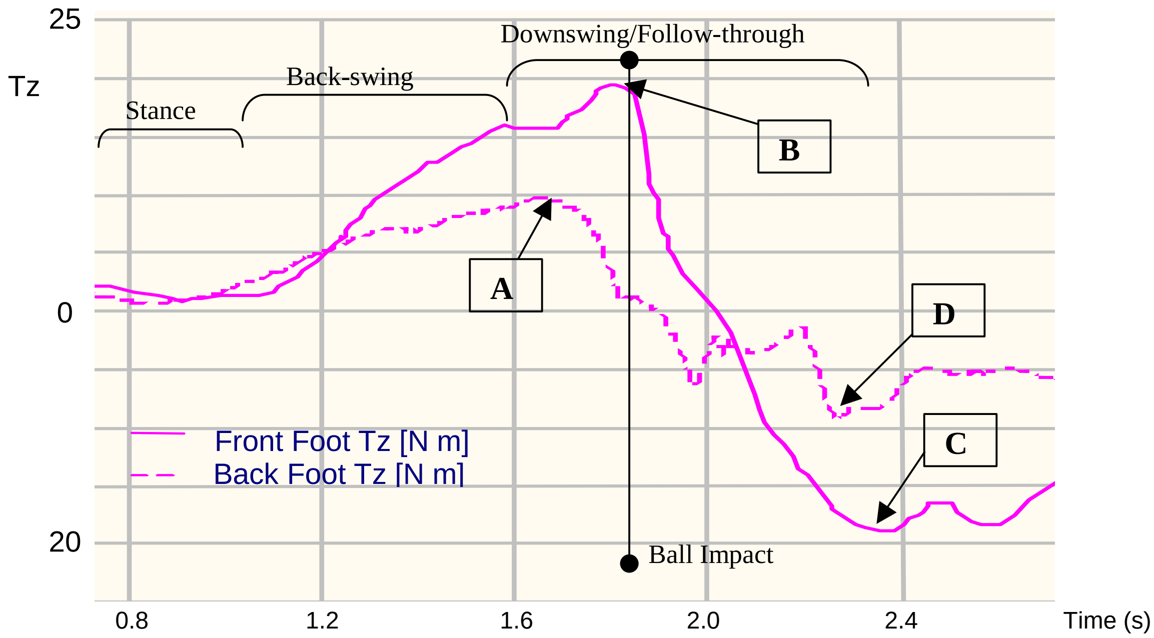

Figure 4. Rotational action force trace identifying the stages of the golf swing with a driver by a low handicap golfer weighing 798N. A = Maximum back foot; B= Maximum front foot; C= Minimum front foot; D= Minimum back foot;

The results shown in table 2 identified greater torque at the front foot than at the back foot during the dynamic swing with a driver. The higher values are a result of the faster more explosive rotations identified during the downswing and follow-through in which the golfer's body weight is transferred onto the front foot. During this phase the front foot is required to act as a pivot point for the body and club to rotate and decelerate around. The forces applied by the golfer on the front shoe to control and decelerate their body movements and club result in the higher front foot Tz rotational forces.

Table 2. Tz rotational forces (mean ± SE) of right-handed golfers with a driver.

Foot	Shoe	Tz Max (Nm)	Tz Range (Nm)
Front (Left)	7 spike	19.599 ±1.771	42.97 ±2.45
	6 spike	19.324±1.597	41.57 ±3.75
Back (Right)	7 spike	8.137 ±0.564	17.58 ±1.02
	6 spike	9.458 ±1.102	14.82 ±1.51

Table 2 indicated that the Tz maximum forces were similar for both shoes, although greater for the front foot than the back foot. However at the back foot the Tz range generated was notably greater at a mean 17.58 Nm for the 7-spike shoe than for the 6-spike shoe design for which a mean Tz of 14.82 Nm was recorded and this difference was significant (P<0.05). The rotational Tz force was similar at 42 Nm approximately for both the 7 and 6 spike shoe designs at the front foot.

DISCUSSION: Greater forces in the vertical and horizontal planes were generated at the sole interface of the front foot than the back foot during driving. This occurred when both the shoe designs were worn and supports observations of Williams and Cavanagh, (1983), Barrentine et al. (1994), albeit determined under very different testing conditions which did not include an ecological natural turf substrate.

During the back swing the back foot generated an anterior to posterior force coupled with the front foot pushing in the posterior to anterior direction creating a clockwise rotation of the body and club. During the anticlockwise rotation of the downswing and follow through the back foot is required to rotate anticlockwise around the fixed medial forefoot of the shoe allowing the golfers body weight to transfer onto and rotate around the fixed front foot / leg. The back foot must facilitate this weight transfer and body rotation whilst enabling the golfer to maintain stability during the follow through and allowing a natural rotational movement of the body through the swing to occur.

The Tz range incorporated the rotational forces of both the back swing and downswing movements during the swing process. When using a driver, the 7-spiked shoe was associated with a significantly greater Tz range within the back foot when compared to the 6-spike shoe design. The 7-spike shoe's greater Tz range within the back swing enabled the golfer to rotate around the foot/leg creating a coiled position with reduced possibility of the shoe slipping under the clockwise force with the accelerated transition into the downswing. However, it should be recognised that such traction does not facilitate the natural movements of the golfer during the latter stages of the swing and follow through. It might be considered likely that the 6 spike shoe sole might provide limited front foot traction during the rotational stages of the swing process, but this was not indicated by the data analysis.

CONCLUSION: The golf shoe with a sole design based on seven alternative spikes allowed the generation of greater torque at the back foot sole-natural grass turf interface than the shoe sole design based upon six alternative spikes.

REFERENCES:

Barrentine, S.W., Fleisig G.S., Johnson, H. (1994). Ground reaction forces and torques of professional and amateur golfers. Science and Golf II. (edited by Cochran, A.J. and Farrally, M.R.) pp33-39. E.and F.N.Spon. London.

Janaway, L. and Dyson, R. (2000). Turf laying system. British patent no: EP1212934.

Williams, K.R. and Cavanagh, P.R. (1983). The mechanics of foot action during the golf swing and implications for shoe design. Medicine and Science in Sports and Exercise, 15, 247-255.

Williams, K.R. and Sih, B.L. (1998). Ground reaction forces in regular-spike and alternative spike golf shoes. Science and Golf III (edited by Farrally, M.R. and Cochran, A.J.) pp568-575. Human Kinetics.