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Research article

Low handicap golfers generate more torque at the shoe-natural grass interface when using a driver

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Abstract
The aim was to determine the rotational torque occurring at the shoe-natural grass interface during golf swing performance with different clubs, and to determine the influence of handicap and golf shoe design. Twenty-four golfers (8 low 0-7; 8 medium 8-14; and 8 high 15+) performed 5 shots with a driver, 3-iron and 7-iron when 3 shoes were worn: a modern 8 mm metal 7-spike shoe, an alternative 7-spike shoe and a flat soled shoe. Torque was measured at the front and back foot by grass covered force platforms in an outdoor field. Torque at the shoe-natural turf interface was similar at the front foot when using a driver, 3-iron and 7-iron with maximum mean torque (Tzmax 17-19 Nm) and torque generation in the entire backswing and downswing approximately 40 Nm. At the back foot, torque was less than at the front foot when using the driver, 3-iron and 7-iron. At the back foot Tzmax was 6-7 Nm, and torque generation was 10-16 Nm, with a trend for greater torque generation when using the driver rather than the irons. The metal spike shoe allowed significantly more back foot torque generation when using a driver than a flat-soled shoe ($p < 0.05$). There was no significant difference between the metal and alternative spike shoes for any torque measure ($p > 0.05$), although back foot mean torques generated tended to be greater for the metal spike shoe. The golf shot outcomes were similar for low, medium and high handicappers in both metal and alternative spike shoes (metal: 87%; 76%; 54%; alternative: 85%; 74%; 54% respectively). The better, low handicap golfers generated significantly more back foot torque (metal spike: 18.2 Nm; alternative: 15.8 Nm; $p < 0.05$) when using a driver. Further research should consider back foot shoe-grass interface demands during driver usage by low handicap and lighter body-weight golfers.

Key words: Cleat, golf, iron, shoe, spike, traction.

Introduction

The golf swing, performed to project the golf ball into flight, is a complex dynamic movement. The degree to which the force produced by the body musculature is transferred to the ball depends upon the reaction force from the ground against the feet (Carlsoo, 1967). Traction at the golfer's feet has traditionally been achieved by using relatively long 6 or 8 mm metal spikes (Figure 1), which fix into the outer sole of the shoe in order to indent or penetrate the turf of the golf course. However, traditional metal spikes compress and grip grass roots, grass or soil, with the likelihood of creating spike marks. The increased popularity of golf has resulted in more surface damage to courses and putting greens (Hammond and Baker, 2002), and caused the wearing of traditional metal spike golf shoes on many courses to be forbidden or restricted. Such bans resulted in the development of alternative spikes for golf shoes, such as shown in Figure 2. Alternative-spike traction is provided by surface protrusions (or cleats) that penetrate only several millimetres into the turf, and were thought by Slavin and Williams (1995) to be associated with a higher probability of slip. Some shoemakers incorporate additional raised mouldings of various designs between the spike positions to increase outer shoe sole traction during the swing in order to reduce the chance of the foot slip. The modern alternative spike sole design relies on surface area and form to grip the ground rather than long spikes. With the potential for injury and performance impairment arising from an accidental slip, in such a fast, powerful movement as the golf swing, there is the need for realistic, ecologically relevant testing to reassure and inform players, coaches and designers of the performance characteristics of modern golf shoe designs.

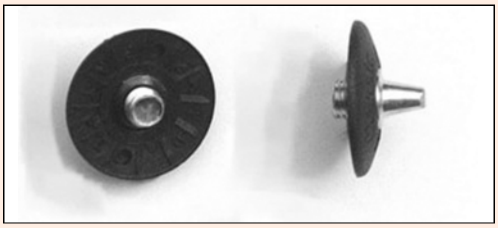

Figure 1. Traditional metal golf shoe spike profile.

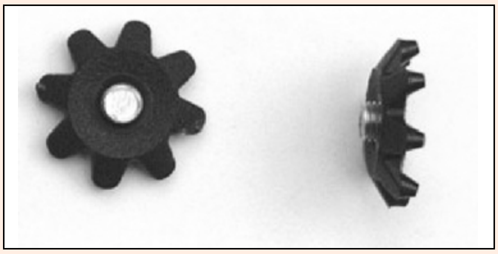

Figure 2. Alternative golf shoe spike profile.

In golf play, the better golfer is given a lower handicap which reflects their golfing ability. The expectations and demands of the low handicap golfer from footwear are likely to be different to those of a high handicap player. The low handicap player is likely to perform fewer golf swings but the needs for effective power generation, control and accuracy are paramount. The game of golf also involves the selection of a number of different types

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of club, designed to aid particular forms of ball flight, in order to reach a hole with the lowest number of shots. The club used for longest shots is the driver and it has the longest shaft and largest club head. The 3-iron and 7-iron are metal irons, which have different lofts to assist ball projectile flight. The 3-iron is often the longest iron carried for long fairway shots. The 7-iron has a shorter shaft and is used for medium to short approach shots. Knowledge of how these key game factors interact during the performance of the golf swing, particularly in relation to the torque generation at the modern golf shoe outer sole to natural turf interface, would aid in questions arising concerning golf shoe selection and design. Laboratory based human studies conducted on artificial turf surfaces have underpinned the scientific knowledge (Barrentine et al., 1994; Dillman and Lange, 1994; Hume et al., 2005; Williams and Cavanagh, 1983). This has inherent limitations because of the induced change in the mechanism of outer shoe sole spike penetration and compression. Williams and Sih (1998), who investigated ground reaction forces when wearing different types of golf shoes on artificial turf, highlighted the need for shoe assessments to be made on a natural grass surface. Worsfold et al. (2007) have reported greater vertical ground reaction force in spiked golf shoes at the shoe-natural turf interface when irons were used in comparison to a driver. It was also noted that greater mediolateral forces occurred across each foot when the driver was used in comparison to the irons. Use of the longer driver club to achieve powerful distance shots involves the generation of more rotational force, and this is likely to impact and interact with maintenance of an adequate support base. Further research is required to confirm the relevance of rotational force (torque) at the shoe-natural grass interface during performance of the golf swing.

The aim of this research was to measure the maximal torque and torque generated at the feet when a driver and two shorter iron clubs were used to perform golf swings on natural grass turf. Also, to identify any differences in torque associated with golfing ability (handicap) or the traction provided by different golf shoe outer sole designs.

Methods

Subjects

Twenty-four right-handed male golfers (mean mass 75.3 SD 9.1 Kg) volunteered for the study and all reported playing three times or more a month. Eight golfers had a low handicap (0-7), eight had a medium (8-14), and eight had a high handicap (15-26). Following university ethical clearance and consideration of the experimental procedural information, each subject provided written consent to participation. All participants were reminded that withdrawal from the study at any time without prejudice was possible. Subjects were allowed as much time as they needed to become accustomed (typically two hours) to the experimental shoes and environment.

Shoes

A traditional golf shoe with 8 mm metal spikes, an alternative spike golf shoe, and a flat soled shoe were assessed. All shoes had leather uppers that were identical in the cases of the metal spike and alternative design shoes. The metal spike shoe (Figure 3) had an ethylene vinyl acetate (EVA) mid-sole, thermoplastic urethane outsole (Adidas Stripe Tournament) and was fitted with 7 Fast Twist™ 8 mm metal spikes. The alternative spike shoe (Figure 4) had an EVA mid-sole and dual density injection moulded polyurethane (TPU) outsole (Adidas Z-Traction Tour) fitted with 7 Fast Twist™ alternative Adidas 5 mm spikes. The flat-soled golf shoe (Figure 5) had an EVA mid-sole, Stilo adapted flat sole and was not fitted with any spikes to provide additional traction. All shoes were new for the research, and a range of sizes was available.

Figure 3. Golf shoe with metal spikes.

Figure 4. Golf shoe with alternative spikes.

Figure 5. Golf Shoe with flat outer sole.

Procedure

Golfers used their own driver, 3-iron and 7-iron. Five shots were performed with each club from a rubber Astro-turf mat, into which a tee could be inserted. Titleist white DT golf balls were used and testing took place in an out-door field setting in good sunny weather. Golfers were asked to play straight shots as normal with each club, and not to draw or fade the ball. The outcome of the each golf shot, whether straight (±8° approximately) or miss-hit was noted. A random testing order was used for both shoe and club type. Golfers adopted their natural golf swing stance with one foot on each force platform. The ground reaction forces of the right and left feet were measured simultaneously on two Kistler 9851 force platforms. The platforms were covered in a natural grass turf surface, similar to that found on a teeing off area on a golf course. The 30 mm deep turf was adhered using a thin slip of clay to smooth plastic plates (Janaway and Dyson, 2000; Smith et al., 2002; 2004; 2006). The plates were screwed onto the top of each force platform and a 35 mm vertical offset applied to account for the plate and turf depth. Force data were passed to two Kistler 9865 amplifiers, which were connected to an Amplicon 12-bit analogue to digital converter. Kistler Bio-Ware 3.1 software controlled data sampling at 1000 Hz and recording of the data to hard disk for storage and subsequent analysis. A 200Hz Peak Performance Technologies camera was placed in front of the golfer to capture whole body and club movement with recording on a Panasonic AG-MD830 video recorder. Posterior lower leg and foot movements were captured with a JVC Compact VHS GR-FX 12EK 50Hz video camcorder to aid in subsequent qualitative analysis to preserve data integrity.

Data analysis

Separate analyses were carried out for torque at the front foot and back foot. In the case of a right handed golfer the front foot would be the left foot and the back foot the right foot. This investigation of the ability of the shoe designs to enable torque generation at the shoe-turf interface during the changes in direction of the swinging club in the frontal plane (from anticlockwise backswing to clockwise downswing and follow-through) revealed associated directional changes in torque generation at the feet (Figure 6). The ability to maintain torque generation at the feet, while the swinging club changes direction from backswing to downswing and follow-through, is critical to the golf swing action and the avoidance of possible foot slip, injury or performance impairment. Hence in this analysis the amount of torque generated (from maximum to minimum torque values to reflect the directional change in torque at the foot interface) was measured in addition to the maximal torque (Tzmax).

Data were checked for its integrity and plotted; a Mauchley's test was used to test sphericity, homogeneity of variance was tested using a Levene's test and a Kolmogorov-Smirnov test was used to assess the normality of the distribution of scores. A three-way ANOVA with repeated measures (Club (driver, 3-iron, 7-iron)*Handicap (low, medium, high) *Shoe (metal, alternative, flat)) was used to identify any significant main effects, and significant differences were identified using a Post Hoc Tukey HSD test (alpha<0.05).

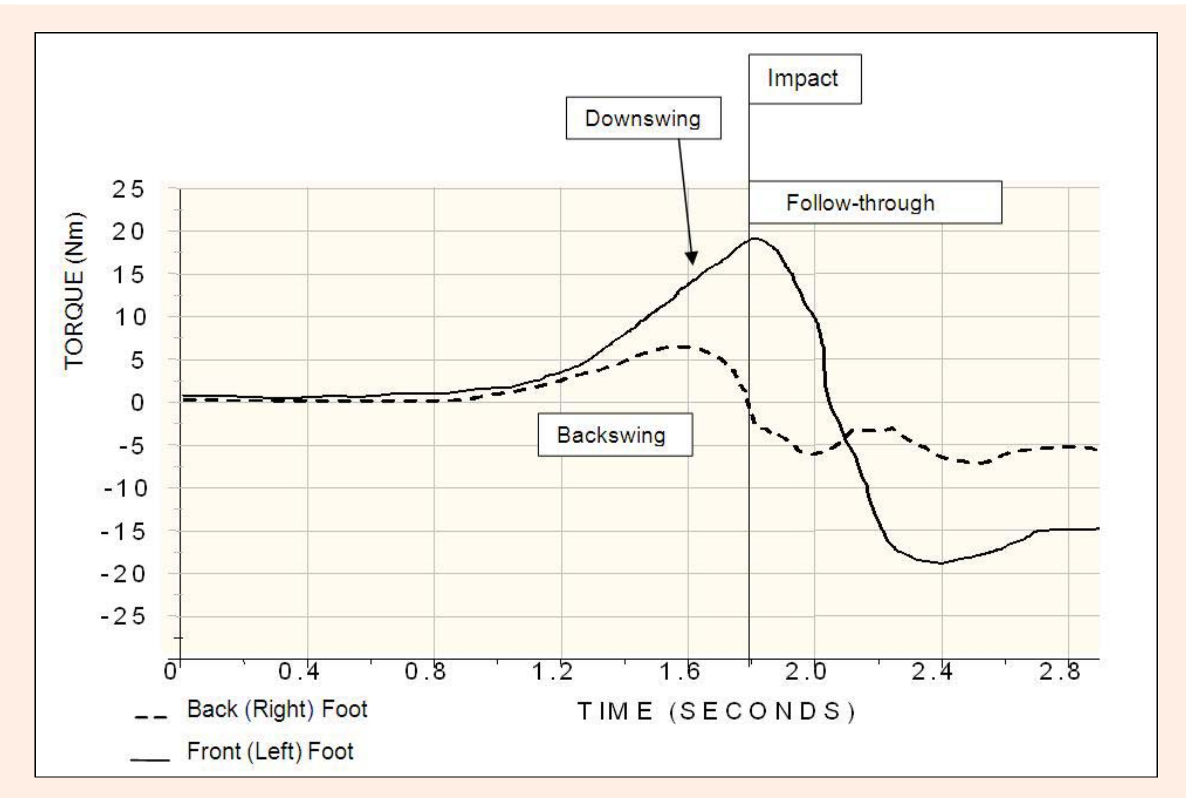

Figure 6. Example torque trace recorded during the golf swing. Note: In the frontal plane for a right handed golfer during the backswing positive rotation is movement to the lateral of the back (right) foot and medial side of the front (left) foot.

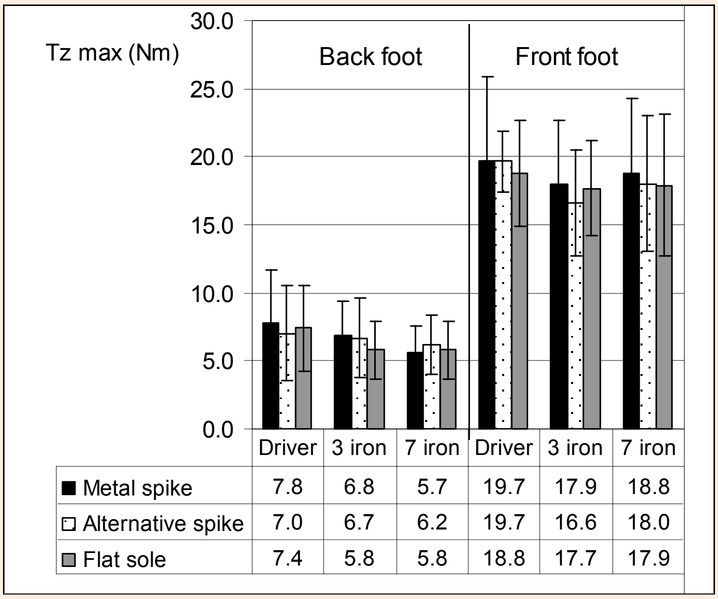

Figure 7. Maximal torque (Tzmax ±SD) at the back and front foot for 24 golfers.

Results

The Mauchley's test of sphericity; Levene's test of homogeneity and Kolmogorov-Smirnov test of normality all revealed non significant findings. Straight shots were achieved in 89%, 71% and 46% of cases by the low, medium and high handicap players respectively. The golf shot outcomes were similar for the low, medium and high handicappers in both the metal spike shoe (87%; 76%; 54% respectively) and in the golf shoe with alternative spikes (85%; 74%; 54% respectively).

The Tzmax recorded (Figure 7) at the back foot in the spiked golf shoes when using the driver and 3-iron was around 7 Nm and slightly less with the shorter 7-iron (6 Nm) for the 24 golfers. At the front foot mean Tzmax in both spiked shoes was nearly 20 Nm when using a driver, but this was only slightly more than when the irons were used (17-18 Nm). For neither back or front foot were the Tzmaz values statistically different when the three types of club were used, and no significant difference was identified for handicap group. Overall the front foot Tzmax on grass turf was 2.7 times greater (16.6-19.7 Nm) than the back foot Tzmax (5.7-7.8 Nm).

Figure 8 illustrates that for all 24 golfers the torque generated at the front foot, whichever shoe was worn, was similar (38-43 Nm) when the three different clubs were

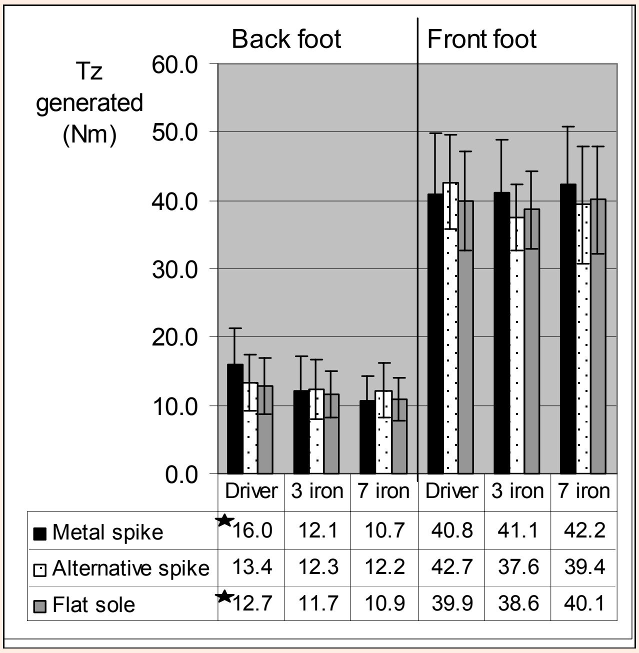

Figure 8. Mean torques (±SD) generated by 24 golfers during the golf swing when three different clubs and three different shoes were worn. * Back foot metal spike shoe torque greater than flat sole shoe ($p < 0.05$).

Table 1. Mean (±SD) torque (Nm) generated at the back and the front foot and variation with handicap, club and shoe type.

			Golfers' handicap		
		Shoe	Low (1)	Medium (2)	High (3)
Driver	**Back foot**	Metal spike	18.2 (3.1) ^{2,3}	15.5 (4.7) ^{1}	14.2 (7.4) ^{1}
		Alternative	15.8 (3.7) ^{2,3}	13.2 (3.1) ^{1}	11.0 (4.4) ^{1}
		Flat sole	14.4 (2.4) ^{2,3}	11.6 (4.0) ^{1}	11.9 (5.6) ^{1}
	Front foot	Metal spike	42.1 (11.0)	40.0 (8.4)	40.4 (9.1)
		Alternative	42.4 (8.3)	42.0 (6.9)	43.5 (5.9)
		Flat sole	38.9 (8.5)	40.0 (6.9)	40.9 (7.1)
3-iron	**Back foot**	Metal spike	12.6 (4.4)	10.9 (2.8)	12.7 (7.8)
		Alternative	11.4 (3.5)	13.6 (6.0)	11.6 (4.6)
		Flat sole	12.4 (4.8)	12.1 (3.0)	10.4 (2.2)
	Front foot	Metal spike	43.4 (8.9)	38.9 (5.3)	40.8 (9.1)
		Alternative	36.3 (4.5)	37.8 (2.7)	38.7 (8.2)
		Flat sole	40.3 (2.9)	37.8 (6.3)	37.3 (7.6)
7-iron	**Back foot**	Metal spike	12.6 (2.9)	9.8 (3.4)	9.5 (4.1)
		Alternative	13.1 (4.1)	10.7 (3.7)	12.7 (4.2)
		Flat sole	12.4 (2.3)	9.9 (2.6)	10.3 (3.9)
	Front foot	Metal spike	41.8 (9.3)	40.0 (6.5)	44.8 (10.0)
		Alternative	40.0 (9.3)	37.1 (6.0)	41.1 (10.7)
		Flat sole	39.1 (8.2)	36.3 (4.4)	42.7 (10.0)

Superscripts indicate significant difference between handicaps for variable ($p < 0.05$).

used. However, for each club the front foot torque generated was much greater than the back foot torque which ranged from 10.7-16.0 Nm. Post hoc analysis indicated that for the driver, the metal spike shoe torque generation at the back foot was significantly more than when the flat sole shoe was worn ($p < 0.01$, Figure 8). This supports the concept that metal spikes provide additional traction.

Consideration of handicap level in relation to torque generation (Table 1), and statistical analysis indicated that handicap did not moderate front foot torque generation. However a trend was evident at the back foot. For each handicap group the torque generated with the driver was greater than the torque generated if the 3-iron or 7-iron was used. Post-hoc analyses revealed that back foot torque generation with the driver by low handicap golfers was greater than torque generated by either the medium or high handicap players, with no difference in torque generated wearing different shoes (Table 1).

Discussion

In contrast to previous research, this study examined ground reaction torque during golf swing performance on a natural grass surface in an outdoor field setting. The interaction of the shoe outer sole and spikes with the natural grass turf will therefore have been quite different to studies which utilised artificial surfaces (Barrentine et al., 1994; Dillman and Lange, 1994; Williams and Cavanagh, 1983). In this study the metal or alternative spikes will have penetrated the grass root structure and therefore the golf stance stability will have been supported in the critical backswing and in the dynamic downswing and follow-through, and it is likely this would be perceived by the golfer. The outdoor testing location would also potentially better replicate the visual and long distance shot natural to the golf course environment than an indoor testing station. The more ecological approach to testing might also influence body posture, with potentially shoe spike penetration and a longer distance visual focus, influencing body posture and movement during the golf swing.

Previous research, using artificial surfaces indoors, focused on orthogonal ground reaction force, and reported maximal forces at each foot, and the weight transfer from the back foot during the backswing to the front foot in the downswing and follow-through (Barrentine et al., 1994; Dillman and Lange, 1994; Koenig et al., 1994; Williams and Cavanagh, 1983; Williams and Sih, 1998). Worsfold et al. (2007) discussed these previous studies and noted the predominant greater maximal front foot ground reaction force measures and asymmetric force generation pattern reported or summarised in most studies other than that of Barrentine et al (1994). Worsfold et al. (2007) reported, for a natural turf based study of golf swing performance, that the maximal vertical forces were less when a driver was used (back foot 0.49 BW; front foot 0.84 BW) than when the 3-iron and 7-iron were used (back foot 0.82 BW; front foot 1.1 BW).

Although the levels of front foot Tzmax in this study (20 Nm approx) were similar to those reported from the artificial turf study by Barrentine et al (1994), the reported similar torque levels of outward rotation at the back foot (peak 22 Nm) and front foot (peak 23 Nm) when using a driver, are not supported by this research. Barrentine et al (1994) reported on handicap level in relation to torque and described similar maximal values for back foot and front foot in the range of 17-26 Nm for all handicaps when Goodyear welted golf shoes were worn. However for PGA and low handicap players, outward rotation was 17-18 Nm for the back foot, and 23-26 Nm at the front foot. Hence, within the better golfers in Barrentine et al.'s study there is evidence of slightly greater maximal outward rotation at the front foot compared to the back foot, but the front to back foot differences in the Tzmax values recorded in this current research were greater.

For all clubs in this natural grass turf based study, Tzmax was greater at the front foot (17-19 Nm) than at the back foot (6-7 Nm). The torque generated was also greater at the front foot (40 Nm) than at the back foot (10-16 Nm). The generated torque values reflected both the negative clockwise and positive anticlockwise rotations of the feet. For the back foot case, the differences between the two torque parameters in figures 7 and 8, for the driver, reflected the greater mean torque generated during the backswing in the metal spike shoe (8 Nm) in comparison to the alternative spike shoe (6 Nm). Worsfold et al. (2006a) compared the metal 7-spike shoe and the alternative 7-spike shoe characteristics using mechanical testing methods on natural grass turf. In comparison to the alternative spike shoe the metal spike shoe provided more forefoot linear (7%) and rotational (31%) traction, and in complete foot to natural turf contact traction was greater for inward rotation (11%) and outward rotation (18%). Hence, the increased torque generation in the back swing observed when the low handicap players wore the metal spike shoe was likely to have been linked to the greater traction in outward rotation provided by the metal spike golf shoe outer sole on natural grass turf. Dillman and Lange (1994) cited research by Richards et al. (1985) which identified that low handicappers had more weight on the shoe heel at the top of the backswing, which would suggest they would be more dependent on complete outer shoe sole traction than less experienced golfers.

There is evidence that detailed dynamic numerical research analyses using groups of subjects can aid in the identification of shoe design characteristics influencing human movement during performance of a golf swing. An alternative 7-spike golf shoe was reported to allow the generation of significantly greater maximal vertical force and torque during golf swing performance with a driver on natural turf than an alternative 6-spike shoe design which had one less alternative spike in the central forefoot toe position (Worsfold et al., 2006a). Case study approaches (e.g. Williams and Sih, 1998) and qualitative observational reports without descriptive statistics or statistical analyses (Koenig et al. 1994), can result in the basis of knowledge being anecdotal in nature (Worsfold et al., 2007).

In this research when using the driver club, better low handicap golfers generated more torque in each type of shoe at the back foot (Table 1). When driving, the difference in torque generation with the metal spike shoe (18.2 Nm) compared to the alternative spike shoe (15.8 Nm), was likely to be linked to the different outer shoe sole performance characteristics determined during mechanical testing.. The metal 7-spike and alternative 7-spike shoe in this investigation provided good traction, and slip did not occur. However this research has shown that, at the back foot the torque generation was greater in the metal spike shoe, and this was particularly of value to low handicap players who had greater torque generation demands. It is recommended that golf shoe designers should consider designing outer sole traction to particularly cope with the torque demands at the back foot interface when low handicappers perform long distance shots with a driver, especially since only approximately 0.5 BW peak vertical ground reaction force acts through the back foot and weight transfer also occurs. In future research and design, consideration should also be given to low handicap golfers of lighter body weight to ensure that their specific torque generation requirements at the back shoe-natural grass interface are addressed.

This experimental research study has revealed that the anecdotal increased force associated with golf driver usage compared to iron usage is misleading, and that the rotational force (torque) generated at the shoe-grass interface is an important component when using the driver. However, ground reaction force variations are important in maintaining stability, and in weight transfer patterns (typically peak 0.3-0.4 BW between feet) that are potentially important in golf coaching (Worsfold et al. 2008) and improving performance.

The results of this experimental study need to be borne in mind when considering the advisability of determining golf shoe selection on indoor testing of golf swing performance, particularly if artificial grass surfaces (or carpet, smooth flooring) are involved in the process. Inclusion of natural grass turf within a testing facility could vastly improve the applicability of golf shoe evaluation and selection.

Conclusion

During the golf swing there is considerable torque generation at the golf shoe-natural grass surface interface. For the driver, 3-iron and 7-iron, the maximal torque (17-19 Nm) and torque generated (40 Nm approximately) were greater at the front foot than at the back foot (6-7 Nm and 10-16 Nm respectively). When using the driver, the metal spike shoe allowed the generation of significantly more torque at the back foot than a flat sole shoe, supporting the importance of outer sole traction in driver swing performance. Also when using the driver, low handicap golfers generated more torque than both the medium and high handicap players. Golf shoe designers should consider designing outer sole traction to particularly meet the demands at the back foot outer sole-natural grass interface when low handicap and lighter body weight players perform distance shots with a driver.

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Key points

- Shoe to natural turf torque generation is an important component in performing a golf swing with a driver club.
- Torque at the shoe to natural turf interface was similar at the front foot when using a driver, 3-iron and 7-iron with Tzmax (17-19 Nm approx) and torque generation in the entire backswing and downswing of 40 Nm.
- Torque at the back foot was less than at the front foot when using the driver, 3-iron and 7-iron; Tzmax was 6-7 Nm, and torque generation 10-16 Nm with a trend to be greater when the driver was used.
- Low handicap golfers generated significantly more torque at the back foot than the medium or high handicappers ($P<0.05$) when using a driver.
- The metal spike shoe on natural turf allowed significantly more torque generation at the back foot than a flat-soled golf shoe when using a driver. Results have implications for golf shoe design.

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