A comparison of two golf shoe designs: Effect of perception and biomechanical testing in elite and recreational golfers

Author: Lasse V. Lock

School of Medicine and Health, Aalborg University, Aalborg, Northern Jutland, Denmark.

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Abstract

Purpose: The study set out to investigate two different golf shoe outer sole configurations in two independent stages: A comfort questionnaire and an indoor laboratory test. **Methods:** Fifteen recreational and elite players volunteered to participate as subject's. For stage I, the questionnaire group, consisting of subjects being both recreational and elite players (age: 27.7 ± 11.3 years; handicap: 7,6 ± 10,7). Subjects were approached on the local golf driving range and tested each pair of ECCO golf shoes before completing the comfort questionnaire. For stage I, each answer and perception of the two different shoes were measured. For stage II, the indoor laboratory test, consisting of subjects being only elite players (hcp:<4; age: 23.75 ± 0.5 years; height: 1.85 ± 0.05 m; body weight: 86.3 ± 5.3 kg). Subjects tested each pair of ECCO golf shoes and completed twenty shots on artificial grass mats in the laboratory setting. Stage II, considered the independent variables shoe (2: Soft spike model and hybrid model design); club (2: 3-wood and 5-iron) in relation to the dependent variables, ground reaction forces (Fy Max) in front and back foot and club head speed and ball speed. A two-way ANOVA was used to compare the independent and dependent variables at a 5% significance level. **Results:** For stage I, the results indicated that the recreational golfers (hcp>4) tend to choose the hybrid shoe model, while elites (hcp<4) tend to choose the soft spike model. Between the subjects participating in the study ~73% would choose the hybrid model compared to ~27% choosing the soft spike model after trying each pair of ECCO shoes. For stage II, no significant difference ($p>0.05$) exists in ground reaction force (Fy Max) between the two variables; club and shoe selection. However, a significant difference exists ($p<0.05$) in simple main effects maximum and minimum (peak) force generation for the back foot within club selection (iron and 3-wood) and within shoes (soft spike and hybrid) used in the study. No significant differences ($p>0.05$) exist in club head speed and ball speed between any of the variables. **Conclusion:** The results indicate that the hybrid model seems to be the general favorite amongst subjects in the comfort questionnaire. The tendency seems to be towards the general population of golfers, while elites/ professionals prefer the soft spike model. Also, no differences were found in ground reaction forces and club head or ball speed suggesting that the hybrid model could potentially deliver similar traction as the soft spike model and thus not affecting the golf swing or outcome.

Introduction

It has been estimated that one hundred fifty thousand people in Denmark, and about fifty-five million people worldwide play the sport of golf (1,2). The popularity of the sport is mostly motivated by the engagement in the natural environments, while being sociable (and active) with other people. The playing and walking benefits of the sport helps to improve cardiovascular health and reduce stress. Throughout the game, golf can be played by all ages and skill levels. In golf, handicaps (hcp) are developed over time and represent how many strokes a player will make over the course of a round. A lower hcp means a better player. In Denmark, the hcp index goes from 54 to +5 and being eligible for playing professional tournaments on must acquire a hcp of 4,4 or lower.

The game of golf is both a sport of distance and accuracy. The distance is enhanced by greater stability, while accuracy is associated with greater stability and lesser mobility (3). The biomechanical lower extremity demands of the golf swing involves two activities: walking and swinging. Walking over the course of a round can extend to 8-10 kilometers, depending on the length of the course. The act of the golf swing is a highly coordinated, multi-level motion, which can be different for everyone. The traditional swing is made up by solid stance, posture and grip while proper foot action is essential for the swing (4).

The swing can be divided into four phases: Address, backswing, downswing and contact/follow through. During the swing, each phase on the front and back foot perform various functions. At address, stability is crucial, while maintaining weight evenly distributed on both feet, with pressure slightly on the forefoot and medial of both feet. At the backswing – the weight is shifted to the back foot, which allows to create more momentum during the downswing. However, excessive lateral weight shift may leave a player unstable resulting in sway which decreases power and may lead to poor ball striking. During the backswing, forces shift from anterior to posterior in the front foot and posterior to anterior in the back foot. This makes the back-foot heel potentially coming off the ground, which is crucial for allowing full shoulder turn. During the downswing, the back foot accelerates the body's center of mass towards the front foot. The momentum of the swing reestablishes the support of the front foot which, like address, allows for upcoming contact with the ball. Ultimately, both feet perform a turning moment which is important for the downswing. The increasing ground reactive forces, with optimal weight transfer from front to back foot increases club-head velocity, which makes feet-to-ground interface an important link in the swing performance. At contact and follow through, 80% of the body weight is shifted to the front foot and as the swing continues, it deaccelerates with pressure finishing on the lateral and heel of the front foot. At finish, the player should be upright, well balanced and facing the target (5).

As mentioned above, the feet play a key role in completing the golf swing. Good foot action during the swing is considered the hallmark of a trained experienced player. Essential for maintaining good foot action is the choice of footwear when playing the game of golf. The golf footwear market has been developing fast, with shoe companies developing lighter, more stable shoes. Historically, golf shoes where of the traditional Oxford model with metal spikes. Nowadays, shoes are comprised of high-tech lightweight materials, which provides less fatigue on the legs during a round of golf. Furthermore, recent design has made golf shoes like cleats, with technologies borrowed from football, cricket and baseball. Today, due to mandatory changes within the golf shoe spike requirements, golf shoes are currently placed within two categories; Spikeless (hybrid) or athletic (soft spikes) (1).

The hybrid shoe is generally lighter, and have no removeable spikes but has a symmetrical pattern of nubs and ridges on the entire sole. The style is more like sneakers, and the first model was presented in 2010 when worn by professional golfer Fred Couples at the US Masters (ECCO Streets Premiers). This hybrid golf shoe style focuses on comfort and style and the model accounts for currently 40-50% of all golf shoes sold (6). The athletic soft spike golf shoe has cleats which can be replaced when worn out. In addition, they have a high number of nubs and ridges around the cleats, which makes traction even greater. In general, the athletic soft spike golf shoe is wider in the front foot, providing more stability throughout the golf swing (6).

Since the changes within golf shoe requirements, performance of the newer models have raised concerns. Studies suggests that metal spikes along with the alternative soft spikes provide higher traction forces. Both models provide similar forces for both maximal force, force generation and coefficient of friction measures (7). Since switching to the alternative soft spike model, no risk of injury or slippage causing loss of momentum, occurs. However, a comparison between the alternative soft spike model and the hybrid style model, tests performed at the Soft Spikes Advanced Research Center (Raven Golf Club, Phoenix, Arizona) showed that soft spikes provide 70% more traction in wet conditions and holding 32% longer, while dry conditions provide 51% more traction and holding 34% longer, when compared to the hybrid style shoe (6,8). However, no published records exist supporting this.

As mentioned earlier, the newer hybrid style model has become popular amongst recreational golfers. However, it remains to be investigated whether the newer hybrid style golf shoe can be replaced with the alternative soft spike model to provide better comfort and provide the same traction along with reducing risk of slippage and risk of injury while swinging and walking.

Therefore, the purpose of this study was to determine if there exists a difference between the alternative soft spike model compared to the newer hybrid style model. To compare each shoe, two different experimental stages were developed. In Stage I, a group of recreational and elite players filling out a questionnaire after the players were given the opportunity to each shoe model on the driving range while hitting golf balls. Afterwards each player had to fill out a comfort questionnaire, regarding the shoes, answering specific questions regarding both shoe models. For Stage II, to assess shoe performance, a group of elite players participating were testing the shoes at an indoor laboratory facility where they were to hit golf balls while data being recorded with Motion Capture (MOCAP) cameras and force plates. During the golf swing this investigation considered the independent variables shoe (2: Soft spike model and hybrid model design); club (2: 3-wood and 5-iron) in relation to the dependent variables, maximum and minimum (peak) ground reaction forces (Fy Max) in front and back foot and club head speed and ball speed.

Methods

Participants

Fifteen recreational and elite players volunteered to participate as subjects. In Stage I, the questionnaire group, consisting of fifteen male subjects being both recreational and elite players. Characteristics were age: 27.7 ± 11.3 years; handicap: 7,6 ± 10,7. Stage II, the indoor lab group, four subjects were recruited from an elite squad from the local golf club (Aalborg Golf Club) and consisted of subjects being only elite players (hcp < 4). All subjects participating in the study had a Danish Golf Union registered handicap. Following an explanation of the proposed research, each subject signed written informed consent, reporting they were free from any injuries or physical dysfunctions, which may have affected their performance. For Stage II, the male subject group's physical characteristics were age: 23.75 ± 0.5 years; height: 1.85 ± 0.05 m; body weight: 86.3 ± 5.3 kg

Apparatus

Stage I: The players were fitted with the two distinct ECCO golf shoes, with different outer sole configurations. All shoes for the research were new and available in size 42 or 44. Each player was using their own golf equipment. All tests were completed on a driving range using artificial grass mats. The comfort questionnaire was constructed with help from the ECCO Company production team.

Stage II: The equipment used for the swing analysis in the biomechanics lab consisted of a setup with a 4X3 m nylon net to intercept all golf balls, along with two artificial grass mats. The golf balls used for the test was chosen as this was a standard choice within all players participating (Titleist Pro-v1, Model 2015). During the golf swing test, each player could use their own fitted golf clubs. Two AMTI Force and Motion (AMTI Optima HPS, Watertown, MA, USA) force plates were used for the swing sequence test to measure ground reaction forces (Fy Max) separately on each foot. Each force plate measures peak force at left and right side of the force plate. This giving peak values in positive and negative directions (See figure 1).

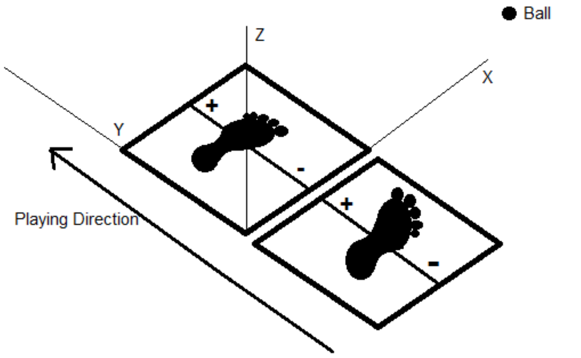

Figure 1. Maximum values occur on the left side of the foot (towards playing direction) while minimum values occur on the right side of the foot (away from playing direction).

The force plates were calibrated to measure a load over the full range of the plate. The system hardware used for MOCAP system was Qualisys (OQUS 300,305,310 Cameras, 8 in total) along with retro reflective spherical markers used to track measurements of club head speed and ball speed. The force plates and cameras were connected to a computer (Dell, Model OptiPlex 5040) where the software Qualisys Track Manager (version 2.15) recorded the data.

Golf Shoes

Both shoe models were used for stage I and II of the study. The ECCO soft spike model was constructed with an advanced cleat system consisting of CHAMP Slim-Lok spikes. Along with the spikes, the shoe was also fitted with thermo-plastic urethane (TPU) reinforced dots. The ECCO hybrid model was constructed with a newer 2018 Tri-Fi-Grip which highlight three areas of the outer sole which has been specifically modified for stability, comfort and durability. The outer sole configurations on both models are as shown on figure 2. and 3. All shoes worn during the tests were new to avoid the chance of outer sole, spike degradation, or wear characteristics influencing the experimental outcome. Each subject was given time to gain familiarity with each type of golf shoe model through playing shots and walking. No time limit was set by the experimenter.

Figure 2. - ECCO Biom Golf Men Hybrid 3

Figure 3. - ECCO Biom Golf G2 Men Soft Spike

Experimental Procedure

The subjects participating in stage I, the comfort questionnaire test, (See Appendix 4.3) were individually approached on the golf course driving range. Ex/inclusion criteria required each player to be a size 42 or 44, as these were the only sizes available for the study. Following provision of consent to partake, each subject had to hit twenty golf balls with each pair of shoes. Afterwards they were required to complete the comfort questionnaire regarding the two different ECCO shoes. The questionnaire was constructed with help from ECCO Company production team.

The subjects participating in stage II, the kinematic data of the indoor laboratory golf swing test were collected using the Qualisys MOCAP system. This is a three-dimensional motion analysis system with eight optical cameras surrounding the subject. Each camera was placed at 4 m from the golf teeing area. A sampling rate of 500 frames per second was used in this study. To ensure the repeatability of all measurements, all cameras were calibrated to a capture rate of 250 Hz using the wand calibration method, according to the manufacturer's guidelines. The cameras were calibrated to the force plate focused area for 60 seconds by applying a perpendicular stick with retroreflective spherical markers. Prior to testing, each subject was fitted with 55 retroreflective spherical markers placed on the body (see worksheet 2.1.4). Each club used was fitted with 5 retroreflective tape markings on most outward tip of the club face, back of the club head and shaft (below grip, middle shaft and hozel). This was done to capture body and club movement by the MOCAP system. Each subject was given a freely chosen number of familiarization swings prior to the actual test, as this was also considered as a warm-up. During testing, each player adopted their natural stance to perform a full swing golf shot with each foot on a force plate. Both force plates were covered with an artificial grass mat, like the ones used on a driving range. Once the golfer had become accustomed to the test environment the player performed 5 shots/swings with own 3-wood and 5-iron towards a directional marker set on the nylon net. Each player was instructed to play a straight shot as they normally would without fading or drawing. The outcome of each shot was recorded with the Qualisys Track Manager. Club and shoe order were randomly assigned for each player.

Data Analysis

To analyze the data from the golf swing test at the indoor laboratory facility, all files in Qualisys Track Manager, from each subject, was converted to tsv files giving data for force plates and retroreflective spherical markers. Each file was analyzed in Microsoft Excel 2016 to give maximum and minimum (peak) ground reaction force (Fy Max) data along with velocity collected from markers set on the club head and ball. Force plate data was filtered giving peak forces for both left and right force plate in two opposite directions (+-). Data for velocity was filtered giving highest velocity for club head before ball impact and highest ball velocity after impact (mm/s). All velocity data were converted to km/h.

Statistical Analysis

Normality of the distribution for outcome measures was tested using the Shapiro-Wilk test, as this test is more reliable when testing > 50 samples. To determine if there were any statistical difference in mean and standard deviation (SD) a two-way ANOVA test was used to compare the independent variables and the dependent variables (2X2) at a 5% significance level and used to calculate the mean differences and SD to further illustrate the data. The data were analyzed using Statistical Package of Social Sciences (SPSS) version 24.

Results

Stage I: Comfort Questionnaire

In the questionnaire, which was handed out to the subjects after playing with each golf shoe model, they answered specific questions regarding their previous experience in golf shoes and their perception of the current golf shoes tested in this study. ~60% of the responses indicated that a hybrid shoe would be their preferred choice, if subjects were to pick between each of the two shoe models, regardless of brand. Before beginning of testing each pair of ECCO golf shoes, subjects were asked to answer the first Likert scale regarding general shoe characteristics. Figure 4 below showing all subjects preferred characteristics from 1 (least important) to 5 (most important) in their current golf shoe choice. Comfort, breathability and fit of shoe are highest ranked characteristics perceived within all subjects with weight of shoe, outer sole configurations (hybrid and soft spike) and cushioning material being the lowest ranked.

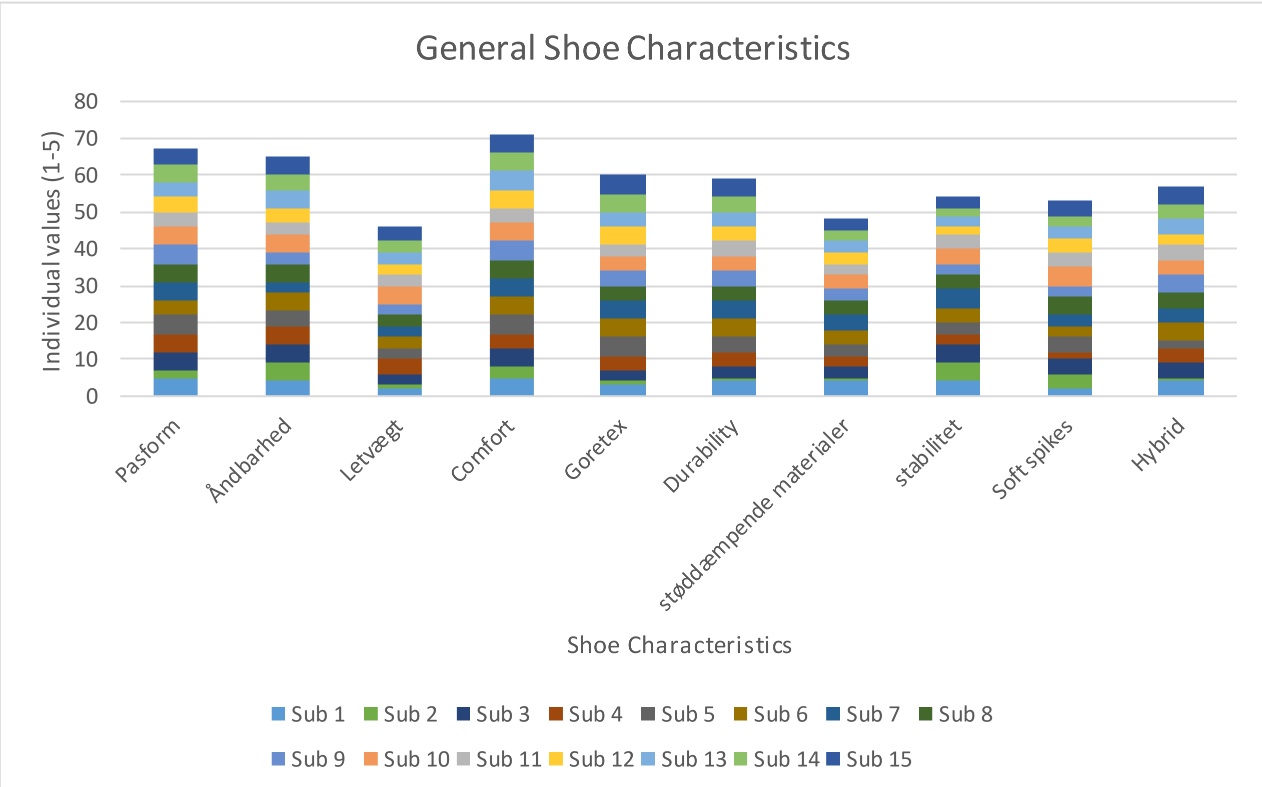

Figure 4. General shoe characteristics amongst all subjects (1 being least important – 5 being most important).

After trying the two ECCO shoe models, subjects were asked to answer the second Likert scale. Figure 5 below showing all subjects preferred characteristics, if they were to buy a new pair of golf shoes, from 1 (least important) to 5 (most important). Quality and fit of shoe being their most preferred characteristics in the buying new golf shoes, with price and brand being the lowest ranked.

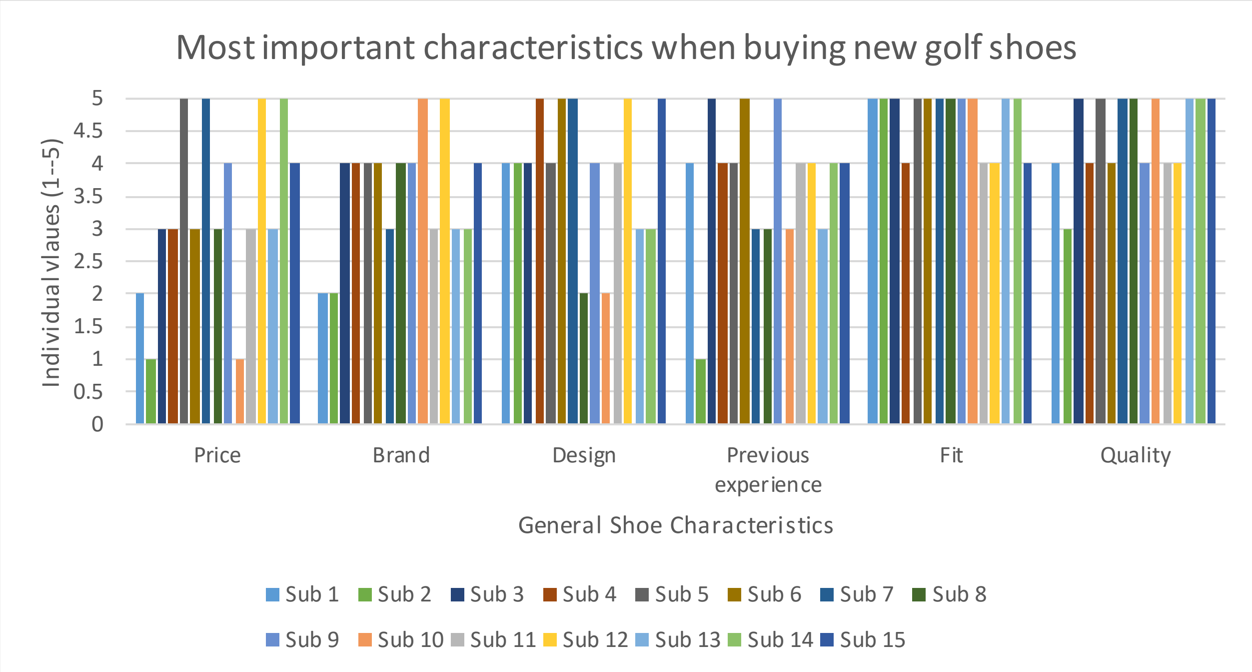

Figure 5. General shoe characteristics if subjects where to buy a pair of new golf shoes (1 being least important – 5 being most important).

After finishing the test of the shoes, each subject was asked which of the two ECCO shoe models they would now prefer. Figure 6 below showing the general tendency being ~73% in favorite of the hybrid shoe model with the soft spike shoe only preferred amongst ~27% of all subjects.

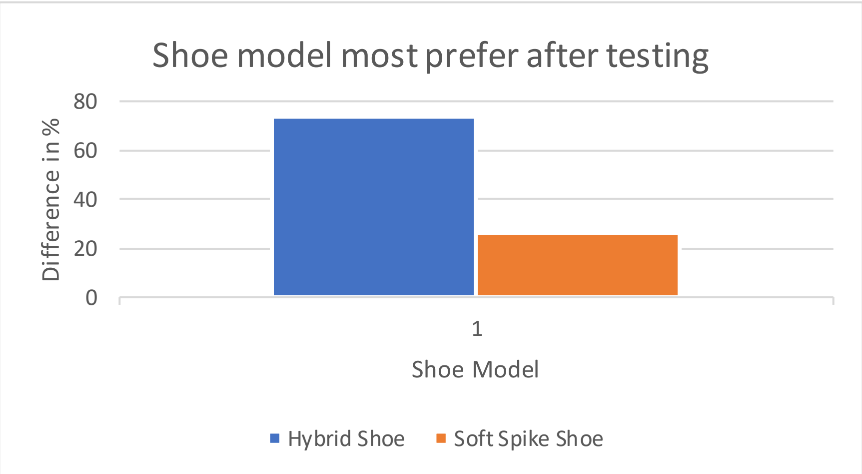

Figure 6. Most preferred shoe model after subjects tried both pair of ECCO golf shoes.

Stage II: Indoor Lab Test

Force Plate

Measurements for maximal ground reaction force (Fy) (table 1 & figure 6) all shown below. Table 1 shows mean values for all subjects in max force generation for the five shots, recorded in N for front foot (left) and back foot (right) with both iron and club while wearing either the hybrid or soft spike model. Average maximum (peak) values are highest measured on left side of the foot, and average minimum values are highest measured on the right side of the foot.

Results show no significant difference (p>0.05) between the two factors; club and shoe selection. However, a significant difference exists in main effects for maximum and minimum (peak) force generation for the back foot within club selection (iron and 3-wood) and within shoes (soft spike and hybrid) used in the study. The results also suggest that the general tendency is that more force is generated with the hybrid model compared to the soft spike model. Furthermore, results also show a tendency towards the left foot generating the highest amount of force on the left side of the foot during the golf swing, however, no significant differences exist between the two factors.

Table 1.	Hybrid Mean Club	Hybrid Mean Iron	Spike Mean Club	Spike Mean Iron
Max Right	75.57 (42.78) *	46.82 (32.63) *	56.54 (42.28) *	29.76 (19.95) *
Min Right	-10.46 (25.23) *	5.94 (13.39) *	4.85 (20.06) *	10.68 (8.64) *
Max Left	52.99 (23.82)	46.17 (20.70)	52.74 (19.30)	46.05 (20.72)
Min Left	-102.86 (20.11)	-86.92 (29.44)	-94.11 (17.92)	-99.66 (29.96)

Table 1. Fy force generation (Right is back foot, left is front foot in playing direction). Data are means (± SD)
$p > 0.05$

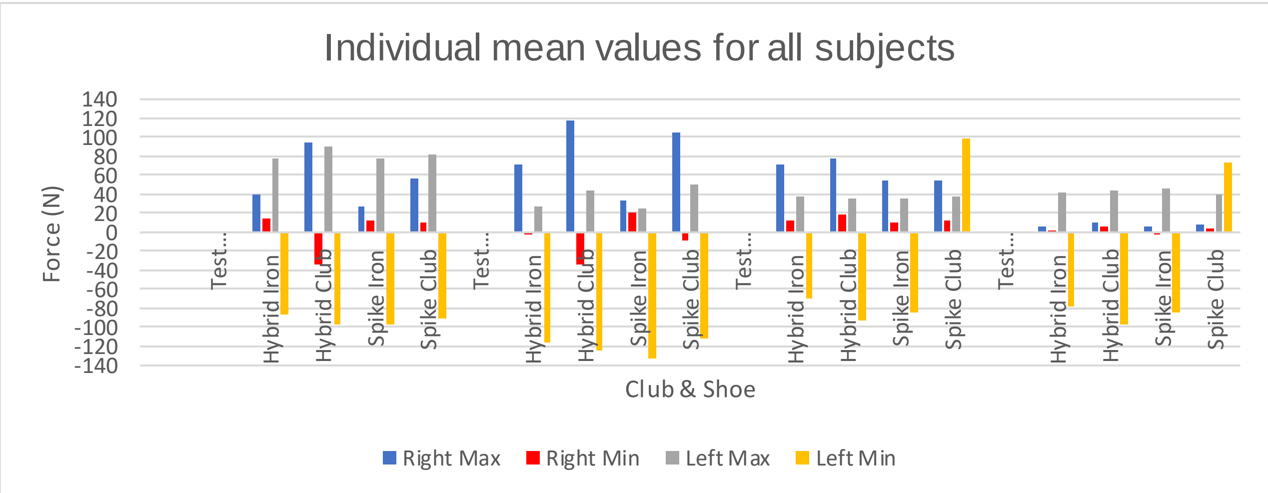

Figure 7. Individual maximum and minimum values for front and back foot. Each value is average of 5 shots hit with either club or iron and with either hybrid or soft spike shoe.

Club & Ball Speed

Figure 8 below shows mean club head and ball speed between the five shots, recorded in Km/h. No significant difference exists between any of the factors. Results indicate that the highest club speed and ball speed is generated with the 3-wood compared to the 5-iron, which is to be expected. Furthermore, no significant difference ($p > 0.05$) exist within the values between shoe models or club selection for the club head speed and ball speed with a slight increase of ~1% in club speed and ~2% in ball speed with the spike shoe compared to the hybrid shoe for both iron and club. This indicates that no apparent effects exist between the hybrid shoe or the soft spike shoe when hitting golf shots with either a 5-iron or 3-wood.

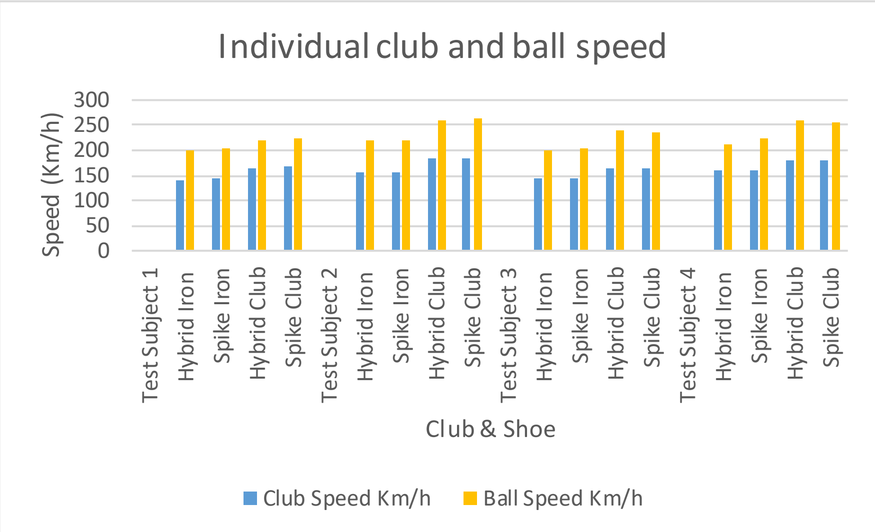

Figure 8. Individual means for club head- and ball speed for all subjects.

Discussion

The purpose of this study was to determine the effects of two different golf shoe models on two separate stages involving stage I: Comfort questionnaire and stage II: Indoor laboratory test measuring maximal ground reaction force along with club head speed and ball speed. The two golf shoes that were assessed were 2017 ECCO soft spike golf shoe and a newer 2018 ECCO hybrid golf shoe. The study focused on whether the two-different outer sole configurations show a significant difference and if the newer hybrid shoe potentially can replace the more traditional soft spike shoe for better comfort while still providing identical traction during the golf swing. The results revealed that for the footwear no significant difference exists between the two golf shoe models or the club selection. However, main effects for maximum and minimum forces in the right foot within shoe models and club selection show significant differences. Furthermore, no significant difference was found within club or ball speed when comparing shoe models and club selection. Club head speed and ball speed showed no significant differences in speed (km/h) between all subjects when switching between shoe models or clubs.

Comfort Questionnaire

At the end of testing, 11 out of 15 responders reported that the ECCO hybrid shoe model would be their preference when choosing a golf shoe. The few subjects not preferring this golf shoe model further elaborated as to why this was the case. Shoe design was the reason why both shoe models were not preferred, along with their general tendency towards soft spikes. Werd et al 2010 reported that elite and professionals in general do not tend to go for versatility when wearing a hybrid golf shoe as opposed to the traditional soft spike golf shoe providing maximal traction. Approximately only 5% of all elites and professionals wear the hybrid shoe style (1). The few subjects in this study not preferring the hybrid shoe model and choosing more towards the soft spike shoe in general, were all elite/professional players with hcp < 0 (1). This indicates that elite players and professionals tend to choose traction and weight in a golf shoe as opposed to the versatility the hybrid shoe model provides.

For the 11 out of 15 subjects, all reported that for general shoe characteristics, comfort is the highest valued. Their preferred golf shoe model was the hybrid shoe model. Regardless of brand, all 11 of these subjects reported that their current golf shoe also was within the hybrid/street style model across varied brands. Furthermore, all 11 subjects would consider switching to the ECCO hybrid model in the future. This indicates that between a larger width of skill levels and ages, the hybrid model seems to be the shoe model most of the individuals would select.

Ground Reaction Force

This research emphasized the demands of force on the front and back feet/shoes comparing two outer sole shoe configurations. Williams and Sih (1998) tested three different golf shoes on artificial turf, however, their study tested older metal spikes friction along with smooth soled shoes and soft spike shoes (9). Their study revealed that soft spikes provided less friction than the metal spikes shoes while smooth soled shoes being the lowest in producing friction. Their findings revealed that the highest amount of force being produced at the front foot. Worsfold et al 2006 reported the same observations (10). This finding is similar with the results found in this study, revealing that the left foot generates a higher amount of force in the medial/lateral (Fy) direction. Furthermore, Worsfold et al 2006, assessed the linear foot and medial and lateral whole feet friction of different shoe-sole interfaces (smooth, metal and soft spike). Their results supported previous findings from Williams and Sih (1998) and Slavin and Williams (1995) highlighting limited friction of smooth soled shoes (9,11). Interestingly, no significant differences were identified between metal and soft spikes shoes. In terms of maximal force, force generation and coefficient of friction, both metal shoes and soft spike shoes produced similar forces. Furthermore, Worsfold et al (2007) found that outer sole shoe design did not significantly increase ground reaction forces on natural grass (7). However, the main determinant of force measures was the type of club used. This means that the shorter clubs used (irons) had a greater force generation compared to clubs (driver/3-wood). However, the mediolateral force generated across each foot in both metal and soft spike when using the driver was greater than when using the irons. This would mean that the soft spike shoe, replacing the metal spike shoe, would not place the golfer at risk of slippage, loss of momentum during the swing sequence, or injury.

Nowadays, since the mandatory changes in golf shoes, soft spikes are considered the ‘golden standard’. Since the newer hybrid model has been introduced to the market in 2011, the Soft Spike Advanced Research Center tested the newer hybrid models against the soft spike models. Their findings supported claims that soft spikes provided 70% more traction in wet conditions and 51% more traction in dry conditions. However, no published records exist regarding specifics of these findings. However, companies like ECCO, Nike, FootJoy etc. claim that the newer generation of hybrid golf shoes provide traction like soft spike shoes found on the market. Even with the small sample size analyzed in this preliminary study, some interesting trends were found. Even though not significant, the ECCO hybrid shoes tends to provide the same, if not higher, amount of medial/lateral force on both the front and back foot in four elite golfers (hcp <4).

Club & Ball Speed

Several other studies have investigated the driving distance in relation to the club head speed and ball speed (12,13,14). However, no studies have investigated the impact of the lower body, especially the implication of the feet, during the golf swing because of the power and forces the legs create. A review by Torres-Ronda et al (2011) analyzed different approaches to golf performance and the improvement of muscle strength (15). Several studies suggested that when training hip-leg and trunk power as well as grip strength is especially relevant for golf performance improvement (16,17). Furthermore, these studies also investigated the difference in hcp and found that golfers playing from scratch (zero hcp) or better had a positive correlation between skill and their muscle strength. This suggests that golfers with low hcp utilize their skill/strength more efficiently, making strength training of the lower body crucial to hitting the ball further (15). When compared to the present study, no apparent effect resides in any of the subjects. This leads to believe that the changing of the outer sole shoe configuration has no effect on club or ball speed. However, when combining strength training of the lower body, club and ball speed can be affected.

For golfers to utilize their ability to hit the golf ball furthest, a term called Smash-factor has been developed, which relates to the amount of energy transferred from the club head to the golf ball (18). The Smash Factor is the ratio between ball speed and club speed. The subjects Smash Factor in the present study seen in table 2 below:

Table 2.	Smash Factor Iron	Smash Factor Club
Test Subject 1	1.42	1.35
Test Subject 2	1.39	1.43
Test Subject 3	1.40	1.45
Test Subject 4	1.35	1.42

Table 2. Mean Smash Factor for all twenty shots hit with iron and club

For tour professionals the average Smash Factor for a 3-wood is 1.49 and 5-iron is 1.41. For elite golfers (hcp < 4) Smash Factor for 3-wood is 1.45 and 5-iron is 1.36 (18). This indicates that golfers in the present study were able to deliver approximately identical results with an average golfer of the same skill level. This would mean that each subject experience no crucial loss of amount of energy transferred to the ball.

Future Implications

To this date, research into the newer hybrid model has not been sufficient. Of the conducted research, focus has been on shoes providing enough friction and mobility for best golfing movement during the golf swing (7,9,10,11). However, it seems that several other factors have a greater importance. With the game of golf being more than just hitting golf balls and long distances often walked during a normal round of golf, further investigations must be conducted to investigate the term ‘comfort’. The subjects perceived comfort during this study relied on a perception of how the shoe felt on their feet along with previous experiences. During a normal round of golf fatigue is not uncommon, however, it can be hypothesized that fatigue can have an impact on performance over the course of a round of golf and possibly their perceived comfort. The challenge to the manufacturer is to try and combine each demand placed upon the shoe during the swinging and walking over the course of a round. However, it is yet to be proven if these requirements golf shoes demand can be met within a single shoe design. At the indoor laboratory facility all shots were performed on level ground and therefore do not consider the undulating fields of nature of a golf course. During a round of golf, golfers experience the possibility of slip and challenging of slopes which could increase the demand upon the shoes and feet. Further research should consider the newer hybrid shoes to natural turf interface with the ground reaction forces and possibly the club head and ball speed that may apply.

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Work Sheet

Theory

Biomechanics of the Golf Swing

The golf swing is a technique a golfer utilizes to hit the golf ball towards a designated target. Through instruction and practice, the golfer develops a coordinated control of multiple muscle groups to produce a golf swing. The golf swing has many moving components, but primarily it focuses on the hip, back, shoulder and leg muscles. During the back swing the arms stay on front of the chest as the shoulders turn. The left deltoid, left latissimus dorsi, right rhomboideus major and left teres major are extended at the top of the swing. The hips create a tension on top of the swing by the restriction of rotational movement. Reaching this position creates the torque, which can lead to produce a high amount of power. In the downswing, to release this energy, the left knee opens forcing the hips to follow. The opening of the hips turns the shoulders with the arms. At impact, once the club reaches the ball, the left quadricep is fully contracting. Both back and shoulder muscles are isometrically contracting allowing to create resistance to get the hands to move past the chest which makes the club accelerate freely through the ball. At follow through the club's momentum carries while deaccelerating with pressure finishing on the outside and heel of the front foot and increasing onto the hallux and the first MPJ of the back foot. At finish the players should be upright, well balanced and facing the target (1,2,3).

Friction – And its effect on the golf swing

During the start of the golf swing, friction is required to facilitate the rotary motions of the golfer and the clubs used. During the back swing, when the golfer's weight is transferred to the back foot, the rotation around the fixed back leg increases the torque centered to the back shoe which makes vertical ground reaction forces peak instantly before reaching the top of the back swing. As the golfer accelerates the club towards the ball during the downswing, until ball contact, the ratio of shear to vertical force is normally at its highest as the golfer's weight is quickly transferred towards the front foot. Any slippage of the feet during the phase of the golf swing would cause a loss of momentum transferred to the ball and the force would be dissipated in the translation of the slipping feet/foot. Slippage like this would also affect accuracy of the club and ball contact making shot outcome potentially bad. The front foot is required to act as a fixed point to allow the body and club to deaccelerate after ball impact (4).

Friction – Football Cleats

Several studies have been conducted into the use of football cleats in sports like football, rugby and American football. The footwear in sports serves three major functions: (1) providing effective and adequate adhesion between feet-to-ground interface, (2) protection of the feet, (3) permit normal foot movement. However, most football cleats fail to in at least one of these requirements. With the amount of friction developed between the shoe and playing surface, it is crucial that players fit themselves with shoes that provide enough traction while protecting them from injuries. The two types of frictional coefficients mostly researched are: translational (sliding) and rotational friction. While it is obvious that frictional resistance must be within an effective range, however, if frictional resistance is to low, slipping occurs, causing injuries. Furthermore, frictional resistance being to excessive will not allow the shoe to 'give' in situations where the load on the leg may cause more acute injury (5).

Several studies have been conducted on the frictional properties of football cleats. Especially between the use of cleats on natural- and artificial grass. Villwock et al 2017 found that the artificial surfaces produced significantly higher peak torque and rotational stiffness than the natural grass surface. Interestingly, the cleat pattern on the shoe did not predetermine the shoe's peak torque or rotational stiffness (5). A study by Ekstrand et al 2006 found comparable results. They reported no significant effects between artificial turf compared to natural grass. Furthermore, no greater risk of injury was found when football was played on either artificial turf or natural grass (6).

When considering ground reaction forces, a study by Smith et al 2004 measured football cleats and football training shoes on a natural grass surface. During fast running the football cleats revealed significantly greater mean vertical impact peak than the football training shoes. Similarly, the mean vertical impact peak loading rate was greater with the football cleat compared to the football training shoe. Interestingly, their study showed that the natural turf ground reaction force measurements can highlight differences in footwear in an ecological environment. However, these finding may have implications for impact-related injuries with prolonged exposure, especially on harder natural turf surfaces. Ground reaction force measures when running in soccer boots and soccer training shoes on a natural turf surface (7).

Golf Injuries

The most common golf injuries for men is being injured in the lower back which account for approximately 30 % of all injuries. Due to the mechanics of the golf swing, the lower back is subjected to a large amount of twisting and sliding with a large amount of ranges and motion. The peak compressive load during the golf swing has been shown to be 8-times bodyweight compared to running/jogging (3-times bodyweight). However, amateurs may also be more susceptible to injury than professionals/elites, since the body movement performed with professionals is close to second nature making it efficient for them to perform the movement. The typical injuries related to the lower back can be increased risk of strains, disc herniation and facet arthropathy (8).

Along with the lower back, the wrist the most common site of injury for golfers. The wrist provides the anchor point of the clubs connecting the arms and shoulders during the swing. The wrist moves through a wide range of motion, which include flexion, extension, radial and ulnar deviation along with pronation and supination of the forearms also being a crucial feature of the golf swing. The most common injury related to the wrist is the result of hitting an object other than the ball. This being an acute nature of injury. This is the results of enough force to disrupt tissue structures. This tend to occur either in the hands and wrists while the elbows also being at risk. Muscular strains and ligamentous strains are common, however, fractures of the hook of hamate may also occur due to this mechanism. Hitting golf shots off hard surfaces like paths, rocks or hard ground can produce similar injuries. The most common type, occurring within this injury, may be the “fat” shot (hitting the ground first during the process of trying the hit the golf ball first). However, this tend to occur mostly within amateurs. In professionals, this type of injury can occur if playing specific tournament like golf courses with thick long rough. This requires a lot of power and speed to get the ball back onto the fairway. The thick grass wraps around the shaft and hozel of the club during ball impact which can place more force on the upper limbs and cause potential injury. Another common injury is tendinitis/tendinopathy which is usually the term indicating an overuse of the mechanism of the golf swing. This is caused by sudden increase in volume of practice or the changing of grip and pressure. It is usually gradually in onset, persistent in nature and continues until the aggravating factor is stopped or rested until allowed proper time to heal (8).

Although knee injuries may not be the most common injury related to golf (approximately 6 %), the forces produced around the knee joint can be large. The right knee reaches its peak force at the top of the back swing when the club is moving slowly (compression 540 N). The left knee reaches its peak force around ball impact and follow-through during the down swing (compression 756 N). With these peak forces required and the fact that many golfers are older, many experience osteoarthritis in the hips or knee because of reduced range of motion. However, the issue of the golf arthritic knee needs to be further evaluated (8).

Although extremely uncommon, some have also experienced fractures of the patellar due to golf. A case study reported by a golfer who experienced a patellar osteochondral fracture during the follow-through of a drive. The internal rotation of the femur on the tibia was the proposed mechanism of the injury. The patella slides over the lateral femoral condyle with the knee in a bent position which can cause an osteochondral fracture of the patella or femoral condyle (8).

Previous Studies – Biomechanical Golf Shoe Testing

It has been a mandatory change within the golf shoe requirements to change the outer sole configurations. Studies performed at the Soft Spikes Advanced Research Center has shown a difference between the hybrid shoe and soft spike model. However, since the hybrid model was first introduced to the market in 2011 a substantial change has happened since. However, it remains to be investigated further the difference between the latest models of hybrids compared to the soft spike model.

Previous studies have suggested that when wearing either the old metal spike model or the alternative soft spike model no significant differences were found on the ground reaction force, compared to the flat soled shoe. However, when testing with different clubs (4-iron, 7-iron and driver) the main determinant of force was the type of club used (9).

A study by Williams & Sih (1998) compared metal and alternative shoe traction designs in terms of force patterns exterted by the feet and the likelihood of slipping during golf shots between five golfers (hcp 8-35). At an indoor lab facility using force plates covered with artificial grass mats, they were able to measure shear and vertical ground reaction forces. Their findings also revealed no significant mean ground reaction force differences ($p > 0.05$) between the alternative soft spike shoe and the metal spike shoe designs during the golf swing. This indicating that golfers showed no signs of slip except in the front foot at or just following ball impact (10).

Another study by Lange et al (1993) suggested that when comparing traditional golf shoes with athletic shoes or running shoes, it shows that shoes with lesser outer sole moldings and no spikes have a higher antero-posterior movement. This indicate that stability during the golf swing is affected more in the antero-posterior direction than the medio-lateral direction. This could indicate a higher risk of injury as slippage could occur during the golf swing (11).

Comfort Questionnaire

A quantitative method is usually the term that covers the surveys or questionnaires. The purpose of this method is to acquire quantitative data through populations with constructed interviews or self-completed surveys. This quantitative method has the possibility to achieve knowledge within certain areas which can be measured and quantified by numbers.

Since this is a sample size survey, the size of the population answering cannot be considered representative throughout the whole group. The sample size is characterized by predictive statistics, which means that it shows what to be expected of the questionnaire if done on a larger group or sample. A sample size survey is often used as a precursor for a larger investigation (12).

Before approaching participants on the driving range with the questionnaire a pilot test was completed. To ensure the validity and reliability of the questions asked, the questionnaire was constructed with knowledge from other studies providing comfort questionnaires, as well as the help from the ECCO Company Production Team which provided the shoes for the study (13).

Regarding the questionnaire setup, the questions asked for the investigation is important in getting the right answers. The questions can be divided into several categories which make for a good questionnaire: (14).

- Background & Factual questions (Age, handicap, golf shoe, shoe size, weekly playing golf, hours playing golf)
- Opinion (Spike or hybrid, shoe characteristics)
- Composite questions (Elaborating further combining factual and opinion)
- Open or closed questions
- Likert Scales

The comfort questionnaire used in the study is a face-to-face interview, in which the interviewer/investigator has an opportunity to answer any doubts or uncertainties that may arise. For the interviewer being on site, at the golf driving range, gives a higher response rate, however this method can be more time consuming and expensive. This approach was done to minimize possible bias in terms of misunderstood questions and/or phrasing of questions. The benefits of using a questionnaire is getting a large amount of data within a brief period, along with a high reliability because of the structured questionnaire.

In terms of sampling, a so-called convenience sample is used for this questionnaire. For this type of sampling, participants are selected because they were available on the golf course. Each participant was selected on the driving range only with the ex/inclusion criteria of shoe size (42 and 44) (14).

Methodology

2. Equipment

2.1.1 Golf Setup

The equipment used for the study were set up as following: Two artificial grass mats placed side by side on top of two AMTI Force and Motion (AMTI Optima HPS, Watertown, MA) force plates (See figure 1.1 & 1.2). All data recorded were obtained using a stationary computer (Dell, Model OptiPlex 5040) with the Qualisys Track Manager (version 2.15) (See figure 1.3).

Figure 1.1

Figure 1.2

Figure 1.3

2.1.2 Qualisys Motion Capture

The system hardware used for motion capture were Qualisys (eight OQUS 300 series cameras) (See figure 1.4). Spherical markers were placed on each subject at specific locations, which the cameras would detect. Cameras were connected to a computer with software Qualisys Track Manager (Version 2.15).

Figure 1.4 – Qualisys OQUS Camera used for tracking markers in the golf swing test.

2.1.3 Ecco Shoes

Figure 1.5 – Pictures of both ECCO shoe model used in the golf swing test. The two upper pictures present the ECCO Biom Golf G2 Men's soft spike model, while the two lower pictures present the ECCO Biom Golf Hybrid 3 Men's model.

2.1.4 Retro Spherical Markers – Qualisys Track Manager (Version 2.15)

The marker placement in this study is one of many possible combinations. During the golf swing test, each player was fitted with retro spherical markers on the body. These markers were placed on the body (see figure 1.6) allowing the cameras to track the markers and their movement. Each marker was placed directly on the skin with double adhesive tape. On the 3-wood and 5-iron, each club was fitted with retroreflective tape on bottom of the grip, middle of club, club hozel and at the most outward tip of the club face and back of club head. The golf ball was covered in retro-reflective tape, while at the point of impact, where ball meets club, no tape was used.

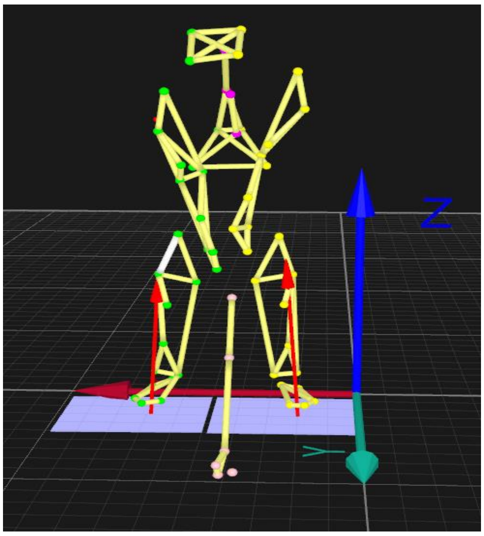

Figure 1.6 – 60 markers placed on body and club to illustrate movement during the golf swing test.

2.2 Protocol

At stage I, the questionnaire, each player was given a selected model in their size and was instructed to hit 20 golf balls on an outdoor driving range. During the test, each player could change clubs as they normally would during driving range sessions. Afterwards, they were to change shoe model and hit same amount of golf balls again. After completion of the test, each player where to fill out a comfort questionnaire.

At stage II, the indoor laboratory group, players could warm-up as they were swinging and hitting golf balls into the net. After warm-up they were equipped with markers and tape for the Qualisys Motion Capture testing. Players were then equipped with the appropriate shoe, selected in their size. After hitting five balls with both 5-iron and driver (10 in total), they changed shoe model between soft spike and hybrid and was instructed to hit same amount of golf balls again.

2.3 Investigator

During testing in stage I and II the same investigator was present to guide and explain for each player. Same procedure was present for all players to ensure reliability, in terms of gathering the same data for the questionnaire and same environment for the laboratory testing.

2.4 Pilot Test

Prior to the actual test a pilot test was completed to ensure both protocol and equipment was functioning as it should. The pilot test was completed by the same investigator who completed testing with all players participating in the study. During testing, the investigator used own golf equipment for the lab testing. The questionnaire was tested along with the production managing team from ECCO company, who provided the shoes for the study.

3. Data Processing

3.1 Statistics

Shapiro-Wilks tests were conducted to analyze if the data collected were parametric (see appendix 4.4). If a larger sample size was used (> 50), the Kolmogorow-Smirnow test can be used to assess normality. If the p-value is below 0.05, the data is non-parametric. The statistics program SPSS (version 25) was used. To compare each of the following independent groups with the dependent groups, a two-way ANOVA (2x2) test was used. This testing method is useful when determining statistical differences in mean and SD between a range of factors. SPSS calculated a p-value from a fixed significance level (α) which determine if there is any evidence to reject the null-hypothesis, which means that no significant difference exists between the several factors. In SPSS the p-value was set to 5 % probability to reject the null-hypothesis.

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