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An electromyographic study of the effect of hand grip sizes on forearm muscle activity and golf performance

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Abstract

The study describes the differences in surface EMG activity of two forearm muscles in the lead and trail arm at specific phases of the golf swing using a 7 iron with three different grip sizes among amateur and professional golfers. Fifteen right handed male golfers performed five golf swings using golf clubs with three different grip sizes. Surface electromyography was used to measure muscle activity of the extensor carpi radialis brevis and flexor digitorum superficialis on both forearms. There were no significant differences in forearm muscle activity when using the three golf grips within the group of fifteen golfers (p>0.05). When using the undersize grip, club head speed significantly increased (p=0.044). During the backswing and downswing phases, amateurs produced significantly greater forearm muscle activity with all three grip sizes (p<0.05). In conclusion, forearm muscle activity is not affected by grip sizes. However, club head speed increases when using undersize grips.

Keywords. Golf, Golf Grip Sizes, Forearm Muscle Activity

Introduction

Electromyography (EMG) is a method commonly used when evaluating muscle function (Hashemi Oskouei et al. 2013). It is a technique that can be applied for assessing and reducing injury risk by predicting the loads placed on the musculoskeletal system (Dickerson et al. 2007). Numerous EMG studies have been performed to analyse various muscles during the golf swing in relation to injuries. These studies have assessed shoulder, upper and lower back, trunk and lower limb muscles (Pink et al. 1990; Kao et al. 1995; Bechler et al. 1995; Horton et al. 2001; Cole & Grimshaw 2008; Lim et al. 2012).

It comes as no surprise that there is a considerable amount of literature on this topic due to the high levels of reported injuries among golfers (McHardy et al. 2006). A recent study documented that up to 60% of professional and 40% of amateur golfers have suffered two or more injuries when participating in the sport (Gosheger et al., 2003). Although professional golfers have better swing techniques and have greater warm-up routines it is likely the increased injury rate arises from several hours of practise per day (Gosheger et al. 2003), resulting in soft tissue musculoskeletal injuries associated with overuse of the specific muscles (Cabri et al. 2009). The most common injuries found within professional golfers were back injuries (35%), followed by wrist (20%) and elbow injuries (10%). Amateur golfers are more affected by elbow (25%) injuries, followed by shoulder (19%) and lower back (15%) injuries caused by poor swing mechanics and improper warm-up routines (Kohn, 1996; Thériault & Lachance, 1998; Gosheger et al., 2003).

Despite the high frequency rate of golf elbow injuries documented, particularly among amateur golfers, only two previous studies have used EMG to evaluate forearm muscle activity in golfers (Farber et al., 2009; Glazebrook et al., 1994). Glazebrook et al. (1994) compared forearm muscle activity when using an arm brace and a jumbo golf grip. However, their study did not investigate the backswing, downswing and the acceleration phases of the golf swing individually and only tested muscle activity in the trail arm (right arm in right-handed golfers), not the lead arm (left arm in right-handed golfer).

Tennis athletes are also highly affected by similar elbow injuries to golfers. Abrams et al. (2012) reported between 31%-51% of amateur tennis players are affected by elbow injuries. Researchers in the field of tennis (Abrams et al. 2012) and golf (Cabri et al. 2009) suggest that the high injury rate could be a result of the golf swing and tennis stroke requiring powerful wrist extension, therefore putting increased stress on the extensor and flexor muscles of the forearm. Medial and lateral epicondylitis are the most commonly documented injuries of the elbow within golfers (Thériault & Lachance, 1998) and tennis players (De Smedt et al., 2007). Medial epicondylitis or "golfer's elbow" occurs more often in the right arm of right handed golfers and is caused by the over exertion of the

Flexor Digitorum Superficialis (FDS) and other flexor muscles in the forearm (Glazebrook et al., 1994; Leach & Miller, 1987). This over exertion can be a results of excessive repetitive muscular contraptions or sudden deceleration of the golf club (Cabri et al. 2009). Conversely, lateral epicondylitis is associated with overuse of the extensor carpi radialis brevis (ECRB) muscle in the forearm during repetitive striking tasks, resulting in primary tendinosis of the muscle (Hatch et al., 2006; Johnson et al. 2007). Several authors have also documented that during dynamic gripping tasks muscle activity increases force transmission and tension to the tendons, which ultimately could result in tendon strain around the elbow area (Bojsen-Møller et al., 2005; Goislard De Monsabert et al., 2012).

In relation to tennis, Nirschl and Ashman (2003) postulated that using different grip sizes on a tennis racquet could cause changes in forearm muscle activity. The authors suggested that a grip that is too small for the athlete would result in them gripping with increased force and excessive rotation of the wrist, therefore increasing muscle activity from the flexor and extensor muscles; whereas a grip that was too large would reduce force and reduce stroke speed. These views are supported by Adelsberg (1986) who reported changes in grip size on the tennis racket demonstrated a change in amplitude of the forearm extensor muscles, which in turn could affect performance. This view is echoed by leading retailers in the golf industry. These manufacturers claim that 75% of golfers use the incorrect grip size. The golf manufacturers add to the views of Adelsberg (1986) and Nirschi and Ashman (2003) by stating that using incorrect grip sizes could make it difficult for golfers to keep the club square at impact, therefore reducing shot accuracy and distance.

Although no data exists regarding the correct grip size for a golf club (Hatch et al. 2006), researchers in the field of ergonomics and occupational medicine have investigated how performance is influenced by tool handle grip size (Sancho-Bru et al. 2003; Edgren et al. 2004; Kong & Lowe 2005). Blackwell et al., (1999) reported a change in grip force when testing four different grip diameters. Hoozemans and Van Dieen (2005) reported minimal muscle activity changes in the flexor and extensor muscles during grip diameter changes. In theory, the optimal handle size should reduce the muscular force required for a gripping task therefore reducing injury rate in activities that require high grip forces (Sancho-Bru et al. 2003).

The purpose of this study was two-fold: (a) To describe the surface EMG activity of the ECRB and FDS in the lead and trail arm at specific phases of the golf swing using a 7-iron with three different grip sizes and (b) To investigate the differences between muscle activity within professional and amateur golfers using the three different grip sizes on the 7-iron.

Methods

Participants

After obtaining ethical approval from the University of the West of Scotland, fifteen right-handed male golfers participated in this laboratory based study. Participants were required to have no elbow or wrist injuries in the past year and no surgery in the identified areas in the past five years. Participants were also required to have a handicap not exceeding 20 to participate in the study. The mean handicap of the group of golfers was 12.6 (range: 1-20). Seven of the fifteen selected golfers were in the professional category (handicap ≤6) and eight in the amateur category (handicap 12-20) (Glazebrook et al., 1994). The mean age of the golfers was 23.3 years (range: 20-32 years) with a mean experience of 9.8 years in the sport (range: 5-12 years). The researchers explained the procedures and purposes of the study to all participants. Informed consent was then obtained prior to testing.

Apparatus

The experimental set-up included: an artificial golf mat placed in the centre of the laboratory; an enclosed golf net located 2m from the golf mat; an 8-camera Vicon Nexus Bonita (Oxford Metrics Ltd, United Kingdom) Motion Analysis System operating at 250Hz positioned around the golfer to record the golf swing motion; a set of eight Surface EMG Transmitters (Myon 320, Schwarzenberg, Switzerland) and Electrodes (AMBU, Cambridgeshire, UK) used to measure muscle activity. A Digital handheld dynamometer (Medical research, Leeds, UK) was required for the participants to perform the MVC contractions. The Surface EMG system was synchronised with the Vicon Nexus Bonita Motion System to facilitate simultaneous data collection. The Voice Caddie Swing Launch Monitor SC 100 GPS (La Mirada, CA, USA) was used to calculate club head speed. The Launch Monitor has been previously validated in-house against the Vicon Nexus Bonita Motion Analysis System and Trackman™ III Golf Swing and Ball Flight Analysis System (Brighton, MI, USA).

For the golf shots, three Taylormade Speed Blade stiff shaft 7-irons (Taylormade, Basingstoke, UK) and Titleist Pro-V1 (Titleist, Cambridgeshire, UK) golf balls were used. Each of the 7-irons had either an undersized, standard or jumbo grip that weighed 0.47N, 0.51N and 0.60N respectively. The 7 iron was chosen as it is the middle iron in a standard set of golf clubs (Glazebrook et al. 1994). All of the grips were provided by Golf Pride (Golf Pride, Peterborough, UK).

Electromyography Procedure

In order to reduce the impedance of the interface between the skin and electrode, the skin was prepared by hair removal from the tested area, as well as skin abrasion and alcohol cleaning. The electrodes were then placed on the ECRB and FDS forearm muscles on the left and right arms (Figure 1). To standardise the placement of the electrodes of the ECRB muscle a line was marked between the lateral epicondyle and the radial styloid process. The ECRB is located in the proximal half of the forearm, just lateral to the line. The electrode for the FDS muscle was placed towards the middle of the forearm, halfway from the ventral midline to the medial border of the forearm. Each of the four muscles being tested had two leads connected directly to the belly of the muscle. The distance between the centroids of the leads was no more than 2cm apart.

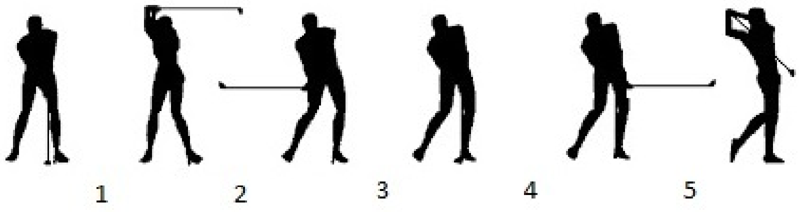
Following the EMG electrodes being secured and the signals verified, participants performed two 3s maximum isometric handgrip contractions in maximum flexion and extension with both hands individually. Participants were given 5 minutes recovery time between each contraction. The highest recording output served as the reference maximal contraction (McCormick et al. 2014). During the contractions, the forearm was secured in a previously validated rig in order to minimize elbow and shoulder movement. The rig held the elbow at approximately 120° during the handgrip recordings (Hashemi Oskouei et al. 2013). All of the EMG data was recorded at 1000Hz and filtered at 20-400Hz. The activity patterns were assessed every 20 milliseconds and expressed as a percentage of MVC (Farber et al. 2009).

Figure 1: Electrodes placed on the FDS and ECRB forearm muscles with transmitters secured to the forearm using Plastic Wrap Cling Film (UK) (Image from Participant 6).

Experimental Design

Prior to collecting golf swing data, participants were asked to perform their usual warm up routine. Participants then tested the three different grip sizes. The order in which the grips were tested was randomised using a processing generator (TextFixer: www.textfixer.com). Each test session consisted of five golf swings. The participants were asked to aim towards a red pole which was situated behind the golf net and advised to take into consideration the accuracy and distance of their normal 7-iron shot. Participants rested for 15 minutes before repeating the identical protocol using the next two grip sizes. The club was swung in five swing blocks. For example, 5 consecutive shots with the standards grip; 5 consecutive shots with the undersize grip; 5 consecutive shots with the jumbo grip.

The golf swing consisted of five phases (Marta et al., 2012) which are defined in Figure 2.



1. **Backswing – From the ball address to the end of the backswing.**
2. **Downswing – From the end of the backswing until the club is horizontal to the ground on the golfer's right side.**
3. **Acceleration – From the club being horizontal to the ground to the point just before ball impact.**
4. **Early follow-through – From ball contact to the club being horizontal on the golfer's left side.**
5. **Late follow-through – From the horizontal club position to the end of motion.**

Figure 2: Silhouette description of the phases of the golf swing.

Data Analysis

The data from the five golf swings was averaged within and between participants. Means and standard deviations (SD) were calculated for the identified forearm muscles during the five phases of the golf swing (Marta et al. 2012). Muscle activity was expressed as a percentage of the MVC. For analysis between participant skill levels, the group was divided into professionals (handicap ≤ 6) and amateurs (handicap 12-20) (Glazebrook et al. 1994). All EMG data was analysed for statistical significance using a one-way ANOVA. The Independent variable was grip size (undersize, standard and jumbo) while the dependent variables were Muscle activity from the forearm muscles and swing speed respectively. An unpaired t-test was used for analysis of the club head speed between professional and amateur golfers. $p<0.05$ was considered statistically significant. All calculations were performed on SPSS (version 22) and Microsoft Excel (version 2010).

Results

All participants showed a similar trend in forearm muscle activity pattern with respect to the grip size during the golf swing. The muscle activity for the two muscles tested in the lead and trail arm for the five phases of the golf swing is displayed in Table 1. The muscle activity recorded during the five golf swings performed by each individual was averaged and averaged again within the group, with standard deviation (SD) also being calculated.

Table 1: Mean and SD for each muscle tested within the three different grip sizes, in percentages of MVC

Grip Size / Phases of the Swing	**Professional** FDS Lead Arm	ECRB Lead Arm	FDS Trail Arm	ECRB Trail Arm	**Amateurs** FDS Lead Arm	ECRB Lead Arm	FDS Trail Arm	ECRB Trail Arm
Undersize								
Backswing	22.91 ± 8.66	52.97 ± 41.47	21.06 ± 14.56	61.02 ± 38.93	33.85 ± 14.15	51.39 ± 29.05	42.17 ± 16.64	63.76 ± 19.48
Downswing	36.05 ± 17.49	47.62 ± 18.49	40.13 ± 19.05	42.28 ± 26.85	89.92 ± 60.70	88.74 ± 39.68	89.18 ± 34.79	56.22 ± 28.89
Acceleration	33.29 ± 29.46	58.76 ± 42.67	40.03 ± 35.37	65.58 ± 65.60	54.91 ± 51.47	56.02 ± 29.45	52.30 ± 23.23	53.32 ± 35.57
Start follow through	24.49 ± 20.98	48.26 ± 47.07	27.10 ± 31.54	39.91 ± 39.09	47.48 ± 38.30	38.22 ± 21.10	35.86 ± 13.46	25.53 ± 16.86
End	16.47 ± 8.66	22.80 ± 23.41	24.28 ± 10.44	14.81 ± 9.29	22.49 ± 10.79	35.35 ± 16.33	37.10 ± 14.53	19.97 ± 10.55
Standard								
Backswing	23.34 ± 8.73	50.58 ± 33.96	20.98 ± 13.52	87.76 ± 56.80	35.87 ± 17.74	50.19 ± 26.45	44.67 ± 16.96	67.41 ± 23.21
Downswing	33.81 ± 14.41	44.56 ± 16.14	44.35 ± 17.89	45.55 ± 20.88	83.92 ± 49.62	80.96 ± 31.84	84.39 ± 33.43	55.88 ± 40.27
Acceleration	37.65 ± 33.43	56.81 ± 35.15	50.73 ± 41.33	69.39 ± 42.05	51.17 ± 45.27	51.87 ± 25.78	49.10 ± 25.17	55.80 ± 37.60
Start follow through	29.76 ± 27.45	53.17 ± 49.58	29.61 ± 30.63	58.81 ± 50.38	47.27 ± 42.99	36.52 ± 19.50	35.85 ± 15.85	31.53 ± 23.18
End	16.65 ± 10.20	24.12 ± 21.92	24.67 ± 9.53	28.61 ± 32.58	21.89 ± 9.22	33.03 ± 15.14	32.12 ± 11.44	21.78 ± 14.65
Jumbo								
Backswing	24.44 ± 9.99	57.10 ± 50.13	20.78 ± 15.33	76.72 ± 47.03	31.99 ± 11.55	47.88 ± 24.83	44.12 ± 18.93	63.73 ± 20.25
Downswing	35.47 ± 14.03	45.24 ± 21.37	38.39 ± 9.32	46.48 ± 21.20	86.70 ± 47.43	83.78 ± 35.41	89.38 ± 29.30	53.73 ± 27.34
Acceleration	36.14 ± 28.18	52.24 ± 21.30	53.30 ± 30.30	65.91 ± 46.06	53.22 ± 36.70	58.41 ± 23.87	50.41 ± 23.21	50.20 ± 40.75
Start follow through	36.58 ± 36.20	52.32 ± 48.51	31.74 ± 25.61	59.88 ± 37.77	46.11 ± 37.68	37.63 ± 22.12	37.09 ± 16.77	24.97 ± 15.45
End	18.92 ± 12.09	22.09 ± 20.39	23.10 ± 8.95	25.57 ± 26.30	22.54 ± 6.72	33.78 ± 13.57	35.97 ± 14.59	17.68 ± 10.53

ECRB - Extensor Carpi Radialis Brevis; FDS - Flexor Digitorum Superficialis

Flexor Digitorum Superficialis

The FDS muscle activity showed no significant differences between the undersize, standard and jumbo grips on the lead or trail arm during the backswing (undersize p=0.969; standard p=0.969; jumbo p=0.987), downswing (undersize p=0.999; standard p=0.999; jumbo p=0.978), acceleration (undersize p=0.990; standard p=0.990; jumbo p=0.871), early (undersize p=0.997; standard p=0.997; jumbo p=0.944) and late follow-through (undersize p=0.892; standard p=0.892; jumbo p=0.945) phases of the golf swing. On average, the standard and jumbo grips had greater muscle activation levels in all five phases of the golf swing on both the lead and trail arm (Table 1). The muscle activity of the FDS in the lead and trail arm peaked on the downswing whilst using all of the grip sizes. During this phase, the jumbo grip produced the greatest muscle activity at 72% of the MVC. During the acceleration phase, the FDS muscle in the lead arm peaked whilst using the standard grip (61% MVC), followed by the jumbo (59% MVC), and finally the undersize grip (46% MVC). Throughout the remainder of the swing on the lead and trail arms, the jumbo grip produced the greatest level of muscle activation, followed by the standard, and finally the undersized grip (Table 1).

Extensor Carpi Radialis Brevis

The ECRB muscle activity showed no significant differences between the undersize (p=0.969), standard (p=0.969) and jumbo (p=0.987) grips on the lead or trail arm during any of the five phases of the golf swing. The muscle activity of the ECRB on the lead arm displayed similar activation patterns during the five phases of the golf swing. The downswing produced the greatest muscle activity, followed by the acceleration phase and then the backswing, with the two follow-through phases producing the lowest muscle activity. The undersize grip produced the greatest muscle activity during the downswing (71% MVC (undersize); 66% MVC (standard); 68% MVC (jumbo)), and the acceleration phases (57% MVC (undersize); 54% MVC (standard); 56% MVC (jumbo)). The three grip sizes displayed similar muscle activity during the three remaining phases (Table 1).

The ECRB muscle on the trail arm showed a different activation pattern to the lead arm. The backswing produced the greatest activation, followed by the acceleration phase and then the downswing phase. The two follow-through phases produced the lowest muscle activity. During the backswing, the standard grip produced the highest muscle activation (75% MVC), followed by the jumbo grip (69%

MVC), and finally the undersized grip (63% MVC). During the acceleration phase the standard grip produced the greatest muscle activity (62% MVC), followed by the undersize grip (59% MVC) and then the jumbo grip (57% MVC). The three remaining phases showed similar activation patterns within all three grip sizes (Table 1).

Professionals versus Amateurs

During the backswing phase there was a significant difference in muscle activation of the FDS in the trail arm between professional and amateur golfers (p=0.029). No significant differences were displayed during the backswing in the FDS of the lead arm (p=0.122) or the ECRB of the lead (p=0.934) or trail (p=0.411) arm. The downswing phase of the golf swing displayed significant differences in the FDS (p=0.035) and ECRB (p=0.026) muscles of the lead arm. With reference to the trail arm, amateurs produced significantly greater muscle activity in the FDS muscle (p=0.021), however, no differences were displayed in the ECRB muscle (p=0.58). During the acceleration, early follow-through and late follow-through phases there was no significant difference (p>0.05) found between the professional and amateur golfers in either of the muscles tested.

Club Head Speed

The undersize grip displayed a significantly greater club head speed compared to the standard and jumbo grips (p=0.044). On average the club head speeds were as follows: undersize 125.51 ± 8.62 km/h; standard: 121.72 ± 8.55 km/h; jumbo 120.35 ± 7.27 km/h.

When comparing the professional and amateur golfers, the professionals had a significantly greater club head speed using all three grip sizes compared to the amateur golfers (undersize: p=0.047; standard: p=0.043; jumbo: p=0.044).

Discussions

Muscle Activity

This is the first study to date that uses surface EMG to analyse the effect of three different grip sizes on muscle activity in the forearm as well as club head speed. This study is also the first to compare muscle activity between professional and amateur golfers when using a 7-iron. On the basis of this study, the results suggest that the standard three grip sizes available to golfers do not change the muscle activity produced by the FDS and ECRB forearm muscles. As a result of these findings, it appears unlikely that a change of grip size would reduce elbow injuries within golfers, especially in the form of lateral or medial epicondylitis. The professional golfers did, however, display significantly lower muscle activity compared to the amateur golfers during a number of phases of the swing. This could explain why amateur golfers are at a greater risk of elbow injuries than professional golfers.

The findings from the current study are in agreement to previous studies that have investigated the effects handle diameter has on forearm muscle activity. Hoozemans and Van Dieen (2005) reported grip diameter had a minimal change on muscle activity from the flexor and extensor muscles of the forearm but this change was not significant. However, this study investigated isometric contractions whereas the current study was examining dynamic movements.

In relation to sport, Hatch et al., (2006) reported there was no significant difference in force produced by the forearm when testing three standard grip sizes available to tennis athletes, and thus it was unlikely grip force had a major effect on forearm and elbow injuries. The researchers did, however, report that forearm extensor muscles showed a decrease in force output whilst using the middle size grip. The current study displays a similar trend, with the middle size grip producing the lowest muscle activity in the ECRB of the lead arm during the backswing, downswing and acceleration phases of the golf swing. Specific to golf, Glazebrook et al., (1994) reported that there was no significant difference in muscle activity in flexor or extensor muscles in the forearm when using a brace or oversized grips when testing symptomatic and healthy patients. These researchers, however, only examined the swing phase as a whole. It could be argued that the golf swing should be subdivided into the backswing, downswing and acceleration phases since it is evident that changes in muscle activity occur at these specific phases. This study also did not take into consideration performance markers such as distance and accuracy. The current research displayed large standard deviations comparable to previously published works. This large within-subject variability is expected when using EMG techniques to evaluate muscle activity (Hashemi Oskouei et al. 2013).

Professional versus Amateurs

Amateur golfers are said to be at a higher risk of developing elbow injuries when compared to professional golfers (Gosheger et al., 2003). These injuries are said to be caused by over exertion of the flexor and extensor muscles of the forearm or poor swing mechanics (McCarroll et al., 1990; Thériault & Lachance, 1998). This study supports these views by displaying significantly increased forearm muscle activity in amateur golfers in comparison to professional golfers at certain phases of the golf swing. During the downswing phase, amateur golfers produced significantly more muscle activity from the FDS and ECRB muscle in the lead and trail arms compared to professional golfers, which ultimately could lead to the elbow area being injured.

The current results are not, however, in agreement with Farber et al., (2009) as the researchers found no significant differences between professional and amateur golfers in the muscle activity produced by the ECRB during the five phases of the golf swing. A plausible cause for these contrasting results could perhaps be the kinematics of the driver swing is different from a mid-iron swing (Egret et al. 2003).

Club Head Speed

The present study suggests that using a smaller grip could increase swing speed and, therefore, increase performance. The undersize grip produced a significantly greater club head speed than the standard and jumbo grips. This increase in club head speed may be explained by the increased muscle activity produced by the ECRB muscle in the lead arm when using the undersize grip during the downswing phase of the golf swing (Table 1). These results are similar to suggestions made by Nirschi and Ashman (2003) who suggest that a large grip may reduce force produced by the extensor muscles and, therefore, reduce stroke speed.

Although the current study suggests an undersized grip increases club head speed, club face angle at impact could not be assessed due to equipment constraints. Leading manufacturers suggest an incorrect grip size can either over or under rotate the wrists during the acceleration phase of the golf swing. Further studies should be performed to access the effects that grip size can have on club face angle at impact. A possible limitation of the study is surface EMG was used to investigate the ECRB and FDS muscles of the forearm; no deep muscles were investigated using fine wire EMG. Finally, the results of the current study may not be applicable to females due to an all-male cohort participating in the study.

Conclusion

To summarise, the results of this study showed that there were no significant differences in the muscle activity produced by the flexor and extensor muscles of the forearm whilst using an undersized, standard or jumbo sized golf grip. This could mean that it is unlikely that changing grip size on the golf club will have an effect on elbow injuries. The current results suggest that professional golfers have significantly lower muscle activity in the FDS and ECRB of the lead and trail arm in the backswing and downswing phases of the golf swing whilst using all three grip sizes tested. This may help towards explaining the discrepancies in elbow injuries between professional and amateur golfers. The results also suggest that an undersized grip does significantly increase club head speed and, therefore, could increase the performance of the golfer. The data may assist clinicians with injury prevention and also help golf coaches improve the performance of athletes.

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