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### 3 **Electromyographic Analyses of the Erector Spinae Muscles during** 4 **Golf Swings using Four Different Clubs**

Graeme G. Sorbie<sup>1,2</sup>, Fergal M. Grace<sup>1,3</sup>, Yaodong Gu<sup>4</sup>, Julien S. Baker<sup>1,4</sup> and Ukadike C. Ugbolue<sup>1,5</sup>

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6 <sup>1</sup>School of Science and Sport, Institute for Clinical Exercise & Health Science, University of the West  
7 of Scotland, Hamilton, ML3 0JB, United Kingdom

8 <sup>2</sup>Division of Sport and Exercise Sciences, Abertay University, Dundee, DD1 1HG, United Kingdom;

9 <sup>3</sup>Faculty of Health, Human Movement & Sport Sciences, Federation University Australia, Ballarat,  
10 Victoria, Australia

11 <sup>4</sup>Faculty of Sports Science, Ningbo University, China

12 <sup>5</sup>Department of Biomedical Engineering, University of Strathclyde, Glasgow, United Kingdom

#### **Corresponding author**

Ukadike Chris Ugbolue

Biomechanics Laboratory,

13 School of Science and Sport,

14 Institute for Clinical Exercise & Health Science,

15 University of the West of Scotland,

16 Hamilton, ML3 0JB,

17 United Kingdom

Phone: +44 (0)1698 283100 Ext 8284

Email: [u.ugbolue@uws.ac.uk](mailto:u.ugbolue@uws.ac.uk)

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1    **Abstract**

2    The purpose of this study was to compare the electromyography (EMG) patterns of the thoracic and  
3    lumbar regions of the erector spinae (ES) muscle during the golf swing whilst using four different golf  
4    clubs. Fifteen right-handed male golfers performed a total of twenty swings in random order using  
5    the driver, 4-iron, 7-iron and pitching-wedge. Surface EMG was recorded from the lead and trail  
6    sides of the thoracic and lumbar regions of the ES muscle (T8, L1 and L5 lateral to the spinous-  
7    process). Three-dimensional high-speed video analysis was used to identify the backswing, forward  
8    swing, acceleration, early and late follow-through phases of the golf swing. No significant differences  
9    in muscle-activation levels from the lead and trail sides of the thoracic and lumbar regions of the ES  
10   muscle were displayed between the driver, 4-iron, 7-iron and pitching-wedge ( $P > 0.05$ ). The highest  
11   mean thoracic and lumbar ES muscle-activation levels were displayed in the forward swing (67 - 99%  
12   MVC) and acceleration (83 - 106% MVC) phases of the swing for all clubs tested. The findings from  
13   this study show that there were no significant statistical differences between the driver, 4-iron, 7-  
14   iron and pitching-wedge when examining muscle activity from the thoracic and lumbar regions of  
15   the ES muscle.

16

17   **Key Words:** EMG, MVC, Thoracic, Lumbar, Club Head Speed

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19

20    **Introduction**

21    The golf swing is a complex movement which requires a coordinated sequence of muscle activity to  
22    efficiently transfer the power and momentum generated by the golf club (McHardy, Pollard, & Luo,  
23    2006). The objective of any golfer is to choose the correct club in order to enable them hit the golf  
24    shot with the optimal accuracy and distance (Egret, Vincent, Weber, Dujardin, & Chollet, 2003).

1 Although golf is thought to be a low-impact sport, biomechanical studies show that many body parts  
2 move at high velocities and through extreme ranges of motion (ROM) during the golf swing (Cole &  
3 Grimshaw, 2008; David Lindsay & Vandervoort, 2014). As a result of these high velocities and  
4 complex movement patterns, the golf swing generates high levels of muscle activity in several areas  
5 of the body (Farber, Smith, Kvitne, Mohr, & Shin, 2009; Kao, Pink, Jobe, & Perry, 1995; Marta, Silva,  
6 Vaz, Castro, & Pezarat-correia, 2015), including the trunk muscles (Cole & Grimshaw, 2008; Horton,  
7 Lindsay, & Macintosh, 2001; Marta, Silva, Vaz, Bruno, & Pezarat-correia, 2013; Luís Silva et al., 2013;  
8 Watkins, Uppal, Perry, Pink, & Dinsay, 1996).

9 As previously mentioned, the trunk muscles are highly active throughout the golf swing and play a  
10 key role in trunk rotation as evidenced by research using electromyography (EMG) (Horton et al.,  
11 2001; Marta et al., 2013; Pink, Perry, & Jobe, 1993; Watkins et al., 1996). The trunk area is composed  
12 of several muscles including: erector spinae (ES), transverse abdominis (TA), rectus abdominis (RA),  
13 internal oblique (IO), external oblique (EO) and abdominal oblique (AO) (Tortora & Derrickson,  
14 2011). During the golf swing, trunk muscles display the greatest activation levels during the forward  
15 swing and acceleration phases (Marta, Silva, António, Pezarat-correia, & Cabri, 2012; Watkins et al.,  
16 1996). A study by Pink et al. (1993) showed that the ES muscle was more active than the AO muscle  
17 on the golfer's trail side (right side for right handed golfers) during the forward swing phase. Watkins  
18 et al. (1996) also displayed similar results that showed the trail ES muscle as being more active than  
19 the upper and lower RA muscle during the forward swing and acceleration phases. Despite these  
20 researchers only focusing on the lumbar ES muscle, it still remains unclear whether or not there is a  
21 correlation in muscle activity patterns between the other regions of the spine.

22 Several rehabilitation (Dolan & Adams, 1993; Larivie, Gagnon, & Loisel, 2000; Vera-Garcia, Ruiz-  
23 Pérez, Barbado, Juan-Recio, & McGill, 2014) and sports specific (Caldwell, Mcnair, & Williams, 2003;  
24 Grimshaw & Burden, 2000) studies have investigated muscle activity levels from thoracic and lumbar  
25 regions of the ES. The ES muscle includes the spinalis, longissimus, and iliocostalis muscles. They play  
26 a vital role in controlling flexion and rotation of the trunk (Loudon, Manske, & Reiman, 2013).

1 Caldwell et al. (2003) investigated muscle activity from the thoracic and lumbar regions of the ES  
2 muscle during rowing motions. These researchers found that the mean EMG amplitude significantly  
3 increased and median frequency significantly reduced during the rowing task, resulting in muscle  
4 fatigue in the three identified regions of the ES muscle. Muscle activation levels in the thoracic and  
5 lumbar regions of the ES muscle have also been investigated during a medicine-ball side-throw task  
6 (Vera-Garcia et al., 2014). These researchers reported distinct differences in muscle activity between  
7 the thoracic and lumbar regions of the ES during the backward phase of the examined movement.  
8 The medicine-ball side-throw task has similarities in movement to the golf swing. These two skills  
9 demonstrate a backward and forward phase, and require powerful trunk muscle contractions during  
10 the forward phase when performing the skill (Lindsay & Horton, 2002; Lindsay & Vandervoort,  
11 2014).

12 Many of the aforementioned golf research reports the influence in club type for the purposes of  
13 data collection (Farber et al., 2009; Horton et al., 2001; Marta et al., 2013, 2015; Sorbie et al., 2016).  
14 Marta et al. (2015) investigated the effect of different golf clubs on lower limb muscles. These  
15 researchers reported statistical differences in muscle activation patterns of the lower limb muscles  
16 when performing golf swings with the 4-iron, 7-iron and pitching wedge. These differences were  
17 generally observed in the forward swing, acceleration and early follow-through phases of the golf  
18 swing. Marta et al. (2013) investigated EMG patterns of trunk muscles when using a long iron (4-  
19 iron) and short iron (pitching wedge). Their results showed that there were no significant differences  
20 in RA, EO and ES muscle activation levels. The researchers did, however, report that there were  
21 increased muscle activity levels when using the 4-iron when compared to the pitching wedge. Whilst  
22 this study has displayed interesting findings, it has some limitations. Firstly, the researchers only  
23 investigated the middle section of the lumbar region of the ES muscle. A study by Grimshaw &  
24 Burden, (2000) showed distinct differences between the upper and lower lumbar region of the ES  
25 muscle, as well as the thoracic region. Secondly, the researchers only investigated a long iron (4-  
26 iron) and a short iron (pitching wedge) but not the driver. Egret et al., (2003) reported kinematic

1 changes to the golf swing when using different golf clubs. Specifically, the researchers reported that  
2 golfers rotated their hips at the top of the backswing between 41 - 63° when using the driver  
3 compared to 42 - 58° when using the pitching wedge. Furthermore, the researchers reported that  
4 the kinematic changes were clearly distinguishable between the driver and the other clubs. It is  
5 reasonable to suggest that these kinematic changes may result in a change in the thoracic and  
6 lumbar ES muscle activity when using clubs of a different length and for a different purpose. Egret et  
7 al., (2003) also reported that the club head speed (CHS) when using the driver was 1.10 times faster  
8 than that of a 5-iron and that the CHS when using the 5-iron was 1.10 times faster than the pitching  
9 wedge speed.

10 The purpose of the current study was to compare the EMG patterns of the thoracic and lumbar  
11 regions of the ES muscle during the five phases of the golf swing when using the driver, 4-iron, 7-iron  
12 and pitching wedge. It was hypothesized that when performing golf swings with the driver, the  
13 thoracic and lumbar regions of the ES muscle would display significantly higher muscle activation  
14 values compared to swings performed by the 4-iron, 7-iron and pitching wedge. Secondly, the study  
15 aimed to describe the CHS, ball speed (BS) and absolute carry distance (ACD) of the golf shot when  
16 using the driver, 4-iron, 7-iron and pitching wedge.

## 17 **Methods**

### 18 **Participants**

19 Fifteen right-handed male golfers who were physically active participated in this study (Effect size  $f <$   
20 0.25). The participants consisted of amateur golfers (Table 1). All participants were required to have  
21 had no upper extremity injuries within the past two months and have no history of lower back pain  
22 and/or persistent musculoskeletal disorders. They were also required to be currently playing golf  
23 regularly each week. All participants completed a physical readiness questionnaire, consent form  
24 and a brief questionnaire about their golfing background (handicap, experience and weekly playing  
25 capacity) before participating in the study. A golfer's handicap is calculated from the lowest score

1 over three rounds of golf (European Golf Association, 2016). Ethics approval was granted by the  
2 XXXXXX Ethics Committee.

### 3 *Table 1*

#### 4 **Electromyography Procedure**

5  
6 The EMG activity was recorded using surface electrodes (AMBU, Cambridgeshire, UK) and a set of 6  
7 Surface EMG Transmitters (Myon 320, Schwarzenberg, Switzerland). In order to reduce impedance  
8 at the interface between the skin and the surface electrode, the participant's skin was prepared by  
9 removing hair from the tested area, followed by skin abrasion and alcohol cleaning. Pairs of surface  
10 EMG electrodes were attached to the skin no more than 20mm apart (centre to centre) over the  
11 lead (left side for right handed golfers) and trail sides (right side for right handed golfers) of the ES  
12 muscle, lateral to longissimus at T8 and L1 levels, and on the multifidus at the L5 level of the spinous  
13 process. Specifically, electrodes were placed 30 mm lateral to the spinous process of the eighth  
14 thoracic vertebrae (T8) (Cheung et al., 2005; Pecos-Martín et al., 2016) and 30 mm lateral to the first  
15 lumbar vertebrae (L1) (Caldwell et al., 2003; Hermens et al., 1999). For the lower lumbar region of  
16 the ES muscle, electrodes were placed on and aligned with a line from caudal tip posterior spina  
17 iliaca superior to the interspace between L1 and the second lumbar vertebrae (L2) interspace at the  
18 level of the fifth lumbar vertebrae (L5) (Grimshaw & Burden, 2000; Hermens et al., 1999).

#### 19 **Electromyography Normalizing Procedure**

20 Prior to EMG recordings, participants performed a 5 minute golf specific warm-up. EMG signals  
21 during a maximum voluntary isometric contraction (MVIC) were then collected as reference for the  
22 normalization procedure. To determine the maximum EMG signal for the thoracic and lumbar  
23 regions of the ES muscle, two isometric repetitions were performed for 4 to 5 s. The MVIC was  
24 performed in the Biering-Sorensen position (prone, with the torso horizontally cantilevered over the  
25 end of a padded test bench). This position was previously used by Vera-garcia et al. (2014) when

1 recording MVIC EMG data from the thoracic and lumbar regions of the ES muscle. Participants rested  
2 for 5 minutes between each repetition in order to avoid the effects of cumulative muscular fatigue.

### 3 **General Procedures**

4 After completing the golf specific warm-up and MVIC process, participants were instructed to hit  
5 twenty golf shots; five with the driver, five with the 4-iron, five with the 7-iron and five with the  
6 pitching wedge. The order in which the golf clubs were tested was randomized using a processing  
7 generator (TexFixer: [www. Texfixer.com](http://www.Texfixer.com)). Participants were advised to take into consideration their  
8 average distance for the four golf clubs tested within the study (Luis Silva et al., 2015). During each  
9 of the golf shots, motion analysis, EMG and golf performance data were recorded. All golf clubs were  
10 provided by Taylormade (Taylormade, Basingstoke, UK). To enable all golf shots to be hit safely, golf  
11 balls (Titleist, Cambridgeshire, UK) were hit from a high shock absorption artificial golf mat  
12 (Longridge, United Kingdom), which was placed in the centre of the laboratory, towards an enclosed  
13 golf net (Sports Net Company, United Kingdom) located 2 m from the golf mat.

### 14 **Video Recording and analysis**

15 For video collection purposes, an 8-camera Vicon Nexus Bonita (Oxford Metrics Ltd, United  
16 Kingdom) Motion Analysis System operating at 250 Hz was positioned around the golfer. The video  
17 data was synchronised with EMG using the same A/D converter. Four retro-reflective markers were  
18 secured to each of the golf clubs being tested. These markers were placed on the base of the grip,  
19 halfway down the club, the hosel of the club, and the club head (Higdon, Finch, Leib, & Dugan,  
20 2012). This enabled the researchers to identify the different phases of the golf swing. The golf swing  
21 was divided into the following phases: (1) the backswing - from the ball address to the top of the  
22 swing; (2) the forward swing - from the top of the swing until the club is horizontal to the ground on  
23 the golfer's trail side; (3) acceleration - from the club being horizontal to the ground to the ball  
24 contact; (4) early follow-through – from the ball contact to the club being horizontal to the ground



1 on the golfer's lead side; (5) late follow-through – from the horizontal club position to the end of the  
2 motion.

### 3 **Electromyography data processing**

4 All EMG data was sampled at 1000 Hz, digitally filtered (15 – 500 Hz) and root mean squared (RMS)  
5 values calculated. For each of the golf shots performed, the average RMS EMG signal was calculated  
6 during each phase of the golf swing. All EMG analyses were performed using the proEMG software  
7 package (Myon 320, Schwarzenberg, Switzerland). The muscle activity recorded during the golf  
8 swings performed by each participant was averaged, and then averaged again within the group, with  
9 standard deviation also being calculated.

### 10 **Performance variables data recording and processing**

11 The Voice Caddie Swing Launch Monitor SC 100 GPS (La Mirada, CA, USA) was used to calculate CHS,  
12 BS and ACD of each golf shot. The Launch Monitor was previously validated in-house against the  
13 Vicon Bonita Motion Analysis System; Trackman™ III Golf Swing and Ball Flight Analysis System  
14 (Brighton, MI, USA). The Launch Monitor was required to be positioned 1 m directly behind the golf  
15 ball and positioned towards the target line of the golfer. After each golf shot, CHS, BS and ACD were  
16 logged using Microsoft Excel. The performance variables recorded during the golf swings performed  
17 by each participant was averaged, and then averaged again within the group, with standard  
18 deviation also being calculated.

### 19 **Statistical Analysis**

20 Normal distribution for all variables was assessed using the Shapiro-Wilk test (McCormick et al.  
21 2014). If normal distribution ( $P > 0.05$ ) was not granted, a log transformation was conducted on the  
22 specific data sets. Following this, a two-way repeated measures ANOVA was performed to explore  
23 the impact of the driver, 4-iron, 7-iron and pitching wedge on normalised EMG values, during the  
24 five phase of the golf swing. All performance variables were analysed for statistical significance using

1 a one-way repeated measure ANOVA. Additionally, all calculations were performed on SPSS (version  
2 22) and Microsoft Excel (version 2010), and  $P < 0.05$  was considered significant.

### 3 **Results**

#### 4 **Comparison between clubs**

5 The muscle activation patterns for the thoracic and lumbar regions of the ES muscle were identical  
6 for the four golf clubs tested during each phase of the golf swing. The lead and trail sides lateral to  
7 the T8, L1 and L5 of the spinous process of the ES muscle displayed no significant interactions  
8 between the clubs ( $P > 0.05$ ). The general tendency was that the swings performed by the driver had  
9 the greatest activation levels compared to the 4-iron, 7-iron and pitching wedge, however, this was  
10 not statistically significant.

#### 11 *Figure 1*

#### 12 **Comparison between phases**

13 During the (1) backswing phase, the lead and trail sides of the ES muscle displayed 27 - 47% of  
14 muscle activation (Figure 1). The three levels of the ES muscle displayed a significant increase in  
15 muscle activation levels from the backswing to the forward swing phase ( $P < 0.05$ ). During the (2)  
16 forward swing phase of the golf swing, the lead and trail sides of the thoracic and lumbar regions of  
17 the ES muscle displayed 67 - 99% of muscle activation. When comparing the forward swing to the  
18 acceleration phase, 4 areas of the ES muscle (lead T8, trail T8, lead L1 and lead L5) displayed  
19 significant increases in muscle activity between the two phases ( $P < 0.05$ ). In contrast, the trail L5 ES  
20 muscle activity significantly reduced between the forward swing and the acceleration phase. No  
21 significant differences were displayed in the trail L1 between these two phases. During the (3)  
22 acceleration phase of the golf swing, the thoracic and lumbar regions of the ES muscle displayed 83 -  
23 106% of muscle activation. Muscle activation levels reduced significantly from the acceleration  
24 phase to the early follow-through phase ( $P < 0.05$ ) and significantly reduced again between the early  
25 follow-through and late follow-through phases ( $P < 0.05$ ) in the lead and trail side of the thoracic and

1 lumbar regions of the ES muscle. During the (4) early follow-through phase of the golf swing, the  
2 thoracic and lumbar regions of the ES muscle displayed 43 - 67% of muscle activation. During the (5)  
3 late follow-through phase of the golf swing, the thoracic and lumbar regions of the ES muscle  
4 displayed 27 - 43% of muscle activation.

## 5 **Performance Variables**

6 The ACD of the driver was 1.40 m greater than that of the 4-iron ( $190.11 \pm 18.32$  m vs.  $135.53 \pm 9.11$   
7 m) ( $P < 0.05$ ). The ACD of the 4-iron was 1.12 m greater than that of the 7-iron ( $135.53 \pm 9.11$  m vs.  
8  $121.31 \pm 10.20$  m) ( $P < 0.05$ ) and the 7-iron was 1.27 m greater than that of the pitching wedge  
9 ( $121.31 \pm 10.20$  m vs.  $95.27 \pm 6.05$  m) ( $P < 0.05$ ).

10 The CHS (Figure 2) of the driver was 1.10 km/h greater than that of the 4-iron ( $150.63 \pm 5.98$  km/h  
11 vs.  $136.94 \pm 4.05$  km/h) ( $P < 0.05$ ). The CHS of the 4-iron was 1.06 km/h greater than that of the 7-  
12 iron ( $136.94 \pm 4.05$  km/h vs.  $129.54 \pm 4.84$  km/h) ( $P < 0.05$ ) and the 7-iron was 1.16 km/h greater  
13 than that of the pitching wedge ( $129.54 \pm 4.84$  km/h vs.  $111.70 \pm 5.82$  km/h) ( $P < 0.05$ ).

14 The BS (Figure 2) of the driver was 1.22 km/h greater than that of the 4-iron ( $208.27 \pm 11.92$  km/h  
15 vs.  $170.60 \pm 7.12$  km/h) ( $P < 0.05$ ). The BS of the 4-iron was 1.07 km/h greater than that of the 7-iron  
16 ( $170.60 \pm 7.12$  km/h vs.  $159.52 \pm 9.48$  km/h) ( $P < 0.05$ ) and the 7-iron was 1.22 km/h greater than  
17 that of the pitching wedge ( $159.52 \pm 9.48$  km/h vs.  $131.13 \pm 6.49$  km/h) ( $P < 0.05$ ).

## 18 **Figure 2**

19

20

## 21 **Discussion**

22 The aim of this study was to compare and describe the EMG patterns of thoracic and lumbar regions  
23 of the ES muscle during the five phases of the golf swing when using the driver, 4-iron, 7-iron and  
24 pitching wedge. It was hypothesized that when performing golf swings with the driver, the thoracic

1 and lumbar regions of the ES muscle would display significantly higher muscle activation values  
2 compared to swings performed by the 4-iron, 7-iron and pitching wedge. The study also aimed to  
3 describe the changes in performance variables when using the driver, 4-iron, 7-iron and pitching  
4 wedge.

5 The results from the current study show that the lead and trail sides of the thoracic and lumbar  
6 regions of the ES muscle activation patterns were identical for the driver, 4-iron, 7-iron and pitching  
7 wedge during each of the five phases of the golf swing, therefore, rejecting the initial hypothesis.  
8 Similarly, Marta et al. (2013) reported that EMG muscle activity from the trunk muscles, including  
9 the ES muscle lateral to the third lumbar vertebrae, did not change when using a 4-iron compared to  
10 a pitching wedge. Additionally, the current study showed that in many cases the longer club  
11 generated greater muscle activation levels, however, this was not statically significant. Marta et al.  
12 (2013) displayed similar findings by stating that muscle activation levels increased when using the 4-  
13 iron in comparison to the pitching wedge. The current research also investigated the use of the  
14 driver and 7-iron clubs and reported that the muscle activity produced when using the driver did not  
15 significantly change in comparison to the iron and pitching wedge clubs. Egret et al., (2003) reported  
16 that the shoulder joint rotation angles and stance are clearly distinguishable between the driver  
17 swing and the pitching wedge. However, it seems unlikely that these kinematic changes have an  
18 effect on muscle activation levels from the thoracic and lumbar regions of the ES muscle on both the  
19 lead and trail sides.

20 Contrary to the findings of the current study and Marta et al. (2013), Marta et al. (2015) displayed  
21 significant changes in muscle activity in the lower limb muscles when examining the 4-iron, 7-iron  
22 and pitching wedge. These contrasting results are likely to be a result of different muscles being  
23 examined within the study. Specifically, the significant changes observed in the study conducted by  
24 Marta et al. (2015) could be associated with the hip extensor muscles requiring greater activation  
25 levels when the shaft length and CHS increases. Keogh et al. (2009) have also shown CHS is  
26 significantly correlated with lower-body strength.

1 With reference to the five phases of the golf swing, the current study displays distinct differences in  
2 muscle activation between these five phases. These findings are similar to Marta et al., (2013),  
3 where the authors reported differences between the phases of the golf swing when examining the  
4 lumbar region of the ES muscle. The results from the current study show that in most cases the trail  
5 thoracic and lumbar regions of the ES muscle are more active than the lead side during the  
6 backswing, especially when using the driver. This may be a result of amateur golfers displaying  
7 significantly more left side bend at the top of the backswing in comparison to higher skilled golfers  
8 (McTeigue, Lamb, Mottram, & Pirozzolo, 1994). A golfer displaying this significant left side bend at  
9 the top of the backswing can be one of the main factors contributing to lower back pain (McTeigue  
10 et al., 1994). It is suggested, therefore, that coaches attempt to amend this error in the swing in  
11 order to reduce injury risk to the trail side of the thoracic and lumbar regions of the ES muscle,  
12 especially when performing swings with the driver.

13 During the forward swing and acceleration phases, the thoracic and lumbar regions of the ES muscle  
14 were at their most active in comparison to the other phases of the golf swing. These finding are in  
15 accordance with previous research examining the ES muscle during the golf swing phases (Marta et  
16 al., (2013). In the majority of cases, the trail side of the lumbar region of the ES muscle was more  
17 active during the forward swing, which is to be expected based on trunk biomechanics of the golf  
18 swing (Marta et al., 2013) and the ES muscle counteracting gravity during this phase. Similarly, Marta  
19 et al., (2013) also reported greater muscle activation levels from the lumbar region of the ES muscle  
20 on the trail side during the forward swing phase. Furthermore, Bulbulian et al., (2001) found that  
21 amateur golfers demonstrate significantly less left side bend during the forward swing phase which  
22 may also result in amateur golfers displaying greater muscle activation in the trail side of the  
23 thoracic and lumbar regions of the ES muscle.

24 During the acceleration phase, the thoracic and lumbar regions of the ES muscle displayed greater  
25 activation levels on the lead side compared to the trail side, especially when using the driver.  
26 Although the acceleration phase is one of the shortest phases of the golf swing, the lumbar spine is

1 exposed to high levels of stress. During this phase, the leftward shift of the hip and the counter-  
2 clockwise direction rotation of the trunk area on the frontal view may result in the higher activation  
3 levels of the lead side in comparison to the trail side (Lim, Chow, & Chae, 2012). These higher  
4 activation levels on the lead side are in agreement with previous research investigating the ES  
5 muscle during the golf swing (Marta et al., 2013). Due to the high levels of muscle activation levels  
6 displayed in both the forward swing and acceleration phases, it is essential for golf coaches to  
7 incorporate correct swing techniques in their instruction, as well as ensuring the golfers having good  
8 physical conditioning of the lower back area.

9 During the early and late follow-through phases, activations levels from the thoracic and lumbar  
10 regions of the ES muscle reduced as the golfer came close to completion of the swing. The muscle  
11 activation levels reduced from the early follow-through phase to the late follow-through phase.  
12 These muscle activation reductions in the final two phases of the golf swing are similar to the results  
13 in previous research examining the lumbar region of the ES muscle (Marta et al., 2013). The ES  
14 muscle on the lead and trail sides showed higher activation values when using the driver compared  
15 to the three irons tested, however, these were not statistically significant. These changes between  
16 the driver and irons may have been caused by the increased spinal rotation required to complete the  
17 driver swing (Gluck, Bendo, & Spivak, 2008) or the increased length of the driver in comparison to  
18 the iron clubs (Egret et al., 2003). The current study displayed high variation in the ES activation  
19 levels, which may be attributed to the high variability in different swing techniques used by the  
20 study participants. Furthermore, this large within-subject variability can be expected when using  
21 EMG techniques to evaluate muscle activity (Hashemi Oskouei, Paulin, & Carman, 2013).

22 In addition to muscle activation levels, this study also investigated the performance variables  
23 between the four clubs tested. The results of the study confirm that the ACD, CHS and BS increases  
24 when the shaft length increases and the loft of the club decreases. The CHS has been previously  
25 investigated with regards to performance variables when using different clubs. Nagao & Sawada.  
26 (1973) showed that CHS when using the driver was 1.34 times faster compared to the CHS whilst

1 using the 9-iron. These results are similar to the current study in that the researchers found that the  
2 driver swing was 1.35 times faster than that of a pitching wedge, which has a shorter shaft length  
3 than a 9-iron and is, therefore, expected to produce a slower CHS. Egret et al., (2003) also reported a  
4 CHS of 161.5 km/h when using the driver and 146.7 km/h when using the 5-iron. These results are  
5 higher than those reported in the current study ( $150.63 \pm 5.98$ ). This increase may be due to the  
6 higher skill level of the golfers who participated in the study conducted by Egret et al., (2003) (mean  
7 handicap:  $0.4 \pm 1.1$ ). Participants in the current study had a higher mean handicap of  $15.2 \pm 5.4$ ,  
8 indicating a lower skill level of golfers in this study than that of Egret et al., (2003). To our current  
9 knowledge, BS and ACD have not yet been investigated in relation to using different clubs. The BS  
10 has, however, been investigated with regards to upper torso and pelvic rotation (Myers et al., 2008).  
11 These researchers showed a mean BS of 200 km/h for golfers with a mean handicap of 15.1 and a BS  
12 of 236 km/h for golfers with a mean handicap of 7.8. As the current study tested golfers with a mean  
13 handicap of 11.3 and a mean BS of 214 km/h when using the driver, the results in this study are very  
14 similar to research published by Myers and colleagues.

15 The results of this study can help clinicians and golf coaches to have a better understanding of the  
16 thoracic and lumbar regions of the ES muscle contribution when using golf clubs with a different  
17 shaft length and loft. The current study may also help these clinicians and coaches have a better  
18 understanding of the golf swing in terms of muscle activation patterns from the thoracic and lumbar  
19 regions of the ES muscle with respect to the phases of the golf swing. The results could help to  
20 develop thoracic and lumbar ES specific intervention programmes to prevent injuries. The current  
21 study has displayed high activation levels in both the thoracic and lumbar regions of the ES muscle.  
22 Inadequate trunk strength and stability may leave golfers more susceptible to developing injuries in  
23 relation to lower back pain.

24 The current study was conducted within a laboratory, therefore ACD had to be calculated from the  
25 CHS and BS and may not give a true reflection of the distance of each shot. This may be seen as a  
26 limitation of the study. Additionally, only right-handed golfers participated in the current study,

1 therefore the results may not be applicable to left handed-golfers. Furthermore, the results of the  
2 current study may not be applicable to females due to an all-male cohort participating in the study.

3

#### 4 **Conclusion**

5 The results of the current study indicate that there are no significant differences in the thoracic and  
6 lumbar regions of the ES muscle activation levels between golf swings performed with the driver, 4-  
7 iron, 7-iron and pitching wedge, therefore it seems unlikely that the risk of injury to the lower back  
8 area will increase when performing swings with the driver compared to the iron clubs. Furthermore,  
9 the results of the current study display distinct differences in muscle activation levels when  
10 examining the five phases. Finally, the greatest thoracic and lumbar ES muscle activation levels were  
11 observed during the forward swing and acceleration phase of the golf swing. The outcome of this  
12 study provides clinicians and coaches with useful physiological parameters that could highlight some  
13 of the potential underlying mechanisms associated with the development of lower back pain.

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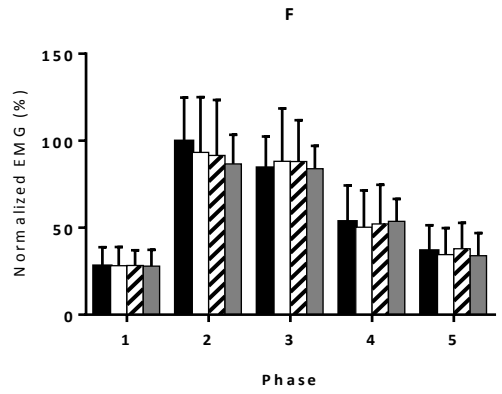
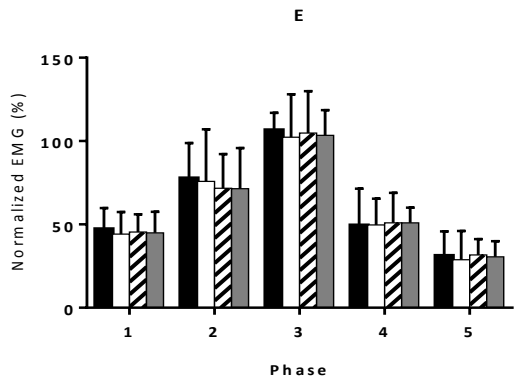
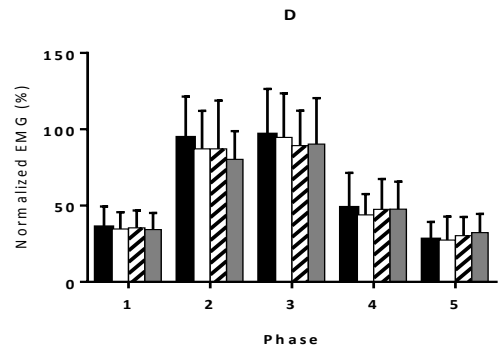
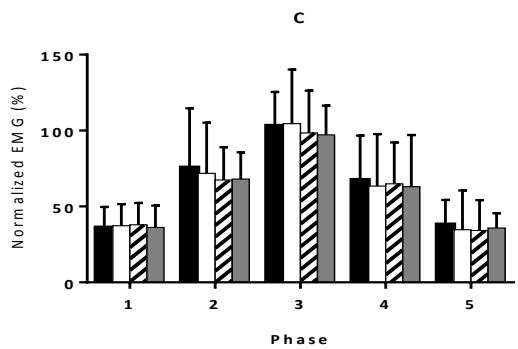
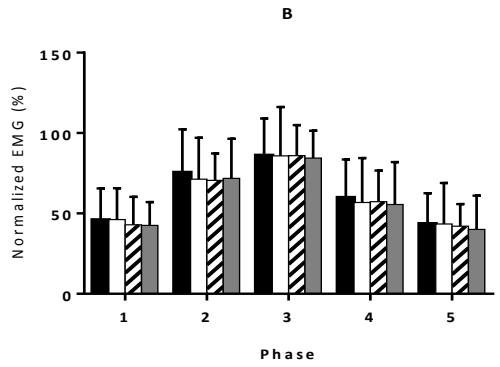
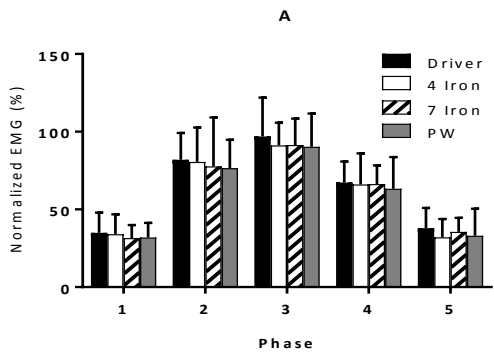
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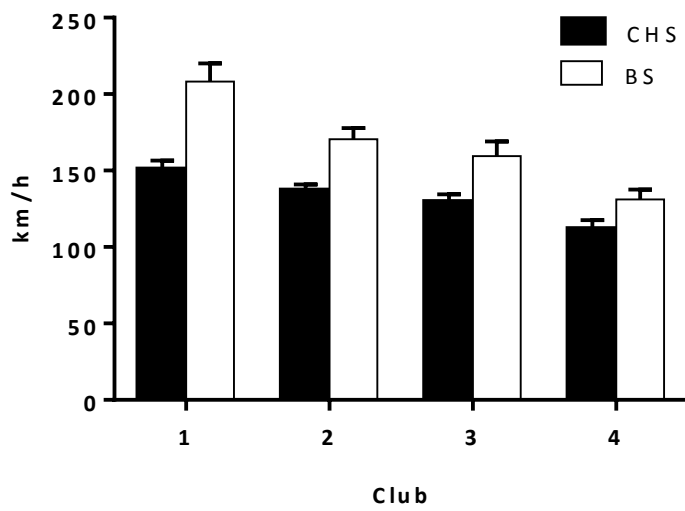
26 Table 1: Participants demographics (n=15)

<b>Demographics</b>	<b>Mean ± SD</b>	<b>Range</b>
<b>Height (m)</b>	1.84 ± 0.1	(1.66 - 1.95)
<b>Body mass (kg)</b>	78.9 ± 11.2	(53.6 - 92.8)
<b>Age (years)</b>	24.9 ± 4.1	(20 - 36.0)
<b>Handicap</b>	15.2 ± 5.4	(10 - 22)
<b>Experience</b>	10.1 ± 4.4	(7-18)

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**Figure 1.** Muscle activity for the erector spinae (A) left T8 ES, (B) right T8 ES, (C) left L1 ES, (D) right L1 ES, (E) left L5 ES, and (F) right L5 ES throughout the 5 phases of the golf swing whilst using the driver, 4-iron, 7-iron and pitching wedge (PW). (1) backswing, (2) forward swing, (3) acceleration, (4) early follow-through and (5) late follow-through phases.



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**Figure 2.** Mean club head speed (CHS) and ball speed (BS) of the 15 participants using the (1) driver, (2) 4-iron, (3) 7-iron, (4) pitching wedge (Mean  $\pm$  Standard Deviation).