

# Comparison of thoracic and lumbar erector spinae muscle activation before and after a golf practice session

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4 **Comparison of Thoracic and Lumbar Erector Spinae Muscle Activation before and**  
5 **after a Golf Practice Session**

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19 **Running Title:** *Erector Spinae Muscle Activation during Golfing*

20

21 **Abstract**

22 Lower back pain is commonly associated with golfers. The study aimed: to determine  
23 whether thoracic and lumbar erector spinae (ES) muscle display signs of muscular fatigue  
24 after completing a golf practice session, and to examine the effect on club head speed, ball  
25 speed and absolute carry distance performance variables. Fourteen right-handed male golfers  
26 participated in the laboratory based study. Surface electromyography (EMG) data was  
27 collected from the lead and trail sides of the thoracic and lumbar ES muscle. Root mean  
28 squared (RMS) EMG activation levels and performance variables for the golf swings were  
29 compared before and after the session. Fatigue was assessed using median frequency (MDF)  
30 and RMS during the maximum voluntary contraction (MVC) performed before and after the  
31 session. Insignificant differences were observed in RMS thoracic and lumbar ES muscle  
32 activation levels during the five phases of the golf swing and performance variables before  
33 and after the session ( $P > .05$ ). Significant changes were displayed in MDF and RMS in the  
34 lead lower lumbar and all trail regions of the ES muscle when comparing the MVC  
35 performed before and after the session ( $P < .05$ ). Fatigue was evident in the trail side of the  
36 ES muscle after the session.

37

38 **Keywords:** *Muscle Fatigue, EMG, Performance*

39 **Word Count:** 3599

40

41

## Introduction

42 Electromyography (EMG) is a study of muscle function that is analysed through  
43 electrical activity. EMG analysis has become an important tool in many areas of research<sup>1</sup>  
44 and has been previously used to predict the loads placed on the musculoskeletal system<sup>2</sup>, as  
45 well as to examine prolonged muscle contractions and estimate localised muscular fatigue.<sup>3-5</sup>

46 EMG techniques have been used to analyse muscle activity in the upper and lower  
47 body during the golf swing.<sup>3,6-14</sup> These studies have assessed shoulder, forearm, upper and  
48 lower back, trunk and lower limb muscles and have mainly focused their attentions on  
49 predicting muscle activation levels in order to reduce injury risks and increase performance in  
50 the sport.<sup>6,14,15</sup>

51 Golf related EMG studies that have investigated the trunk muscles often include the  
52 erector spinae (ES) muscle.<sup>8,13,16</sup> These studies, however, have only investigated the lumbar  
53 region of the ES muscle. The ES muscle includes the spinalis, longissimus and iliocostalis,  
54 which are located in the thoracic and lumbar regions and are pivotal in controlling flexion  
55 and rotation of the trunk area.<sup>17</sup> Several studies which are unrelated to golf have investigated  
56 EMG muscle activity from thoracic and lumbar regions of the ES muscle. These studies are  
57 mainly related to rehabilitation and injury prevention of the lower back.<sup>18,19</sup> Furthermore,  
58 fatigue mechanisms of the thoracic and lumbar ES muscle during isometric contractions have  
59 also been investigated, with the main purpose of evaluating lower back pain.<sup>20,21</sup> Both of  
60 these investigations found increased muscular fatigue in the ES muscle after performing a  
61 specific sporting technique. Horton et al<sup>3</sup> investigated the effect that a golf practice session  
62 has on the abdominal muscles amongst elite golfers with and without lower back pain. To  
63 date, there are no studies that have investigated the fatigue mechanisms of the thoracic and  
64 lumbar ES muscle in golfers.

65 Lumbar muscle function is considered to be one of the most important components in  
66 lower back pain<sup>22</sup> and is reported to be one of the most common musculoskeletal problems  
67 affecting golfers.<sup>23,24</sup> Epidemiological studies have reported that 15-34% of amateur golfers  
68 and 22-24% of professional golfers are affected by lower back injuries.<sup>23</sup> These injuries could  
69 be a result of improper biomechanical movements during the golf swing, poor physical  
70 conditioning or excessive practice.<sup>3,25</sup> Amateur golfers tend to exhibit poorer swing  
71 mechanics and poor physical conditioning, whereas professional golfers are susceptible to  
72 injuries that can be caused by excessive practice and repetitive play.

73 The golf swing requires a large amount of trunk rotation and powerful musculature  
74 contractions, especially in the trunk area during the forward swing and acceleration phases.<sup>25</sup>  
75 With these complex movements being performed on average 60 times per round for amateur  
76 golfers, with professional golfers hitting an average of 40 full shots per round (based on the  
77 golf handicap), it comes as no surprise that many golfers suffer from lower back pain. In  
78 addition to this, during a normal practice session golfers will hit an average of 100 golf shots  
79 with the aim of improving performance.

80 The purpose of this study was threefold: (1) to describe the surface EMG activity of  
81 the thoracic and lumbar region of the ES muscle before and after the golf practice session, (2)  
82 to investigate the changes, if any, in the club head speed (CHS), ball speed (BS) and absolute  
83 carry distance (ACD) before and after the golf practice session and (3) to investigate the  
84 changes, if any, in median frequency (MDF) and root mean squared (RMS) during the  
85 maximum voluntary contraction (MVC) performed before and after the golf practise session.  
86 It was hypothesized that the golf practice session would result in greater localized muscular  
87 fatigue of the thoracic and lumbar ES muscle, leading to the RMS EMG amplitude increasing  
88 after the golf practice session. Secondly, it was hypothesized that the CHS, BS and ACD  
89 would significantly reduce after completing the golf practice session. Finally, it was also

90 hypothesized that the MDF would decrease and RMS would increase during the MVC after  
91 the practice session, resulting in greater muscular fatigue.

## 92 **Methods**

### 93 **Participants**

94 Fourteen right-handed male golfers participated in this laboratory based study (height:  
95  $181.8 \pm 7.9$  cm, weight:  $77.2 \pm 10.7$  kg, age:  $25.4 \pm 4.9$  years, British Golf Association  
96 handicap:  $15.2 \pm 5.7$ ). Participants were required to have no history of lower back pain and/or  
97 persistent musculoskeletal disorders and were required to be playing golf regularly. All  
98 participants completed a physical readiness questionnaire and consent form before  
99 participating in the study. Ethical approval was granted by the University of the West of  
100 Scotland, School of Science and Sport Ethics Committee.

### 101 **EMG Procedure**

102 EMG activity was recorded using 12 surface electrodes (AMBU, Cambridgeshire,  
103 UK) and a set of 6 Surface EMG Transmitters (Myon 320, Schwarzenberg, Switzerland). In  
104 order to reduce impedance at the interface between the skin and the surface electrode, the  
105 participant's skin was prepared removing hair from the tested area, followed by skin abrasion  
106 and alcohol cleaning. Pairs of surface EMG electrodes were attached to the skin no more than  
107 20mm apart (centre to centre) along the expected muscle direction of the lead (left side for  
108 right handed golfers) and trail (right side for right handed golfers) sides of the thoracic and  
109 lumbar ES muscle. Specifically, electrodes were placed 30 mm lateral to the spinous process  
110 of the eighth thoracic vertebrae (T8)<sup>26,27</sup> and 30 mm lateral to the first lumbar vertebrae  
111 (L1).<sup>28,29</sup> For the lower lumbar region of the ES muscle, electrodes were placed on and

112 aligned with a line from caudal tip posterior spina iliaca superior to the interspace between  
113 L1 and L2 interspace at the level of the fifth lumbar vertebrae (L5).<sup>29,30</sup>

#### 114 **EMG Normalizing Procedure**

115 Before the golf swing trials, EMG data from the T8, L1 and L5 areas of the ES  
116 muscle were bilaterally (lead and trail sides) collected during a MVC in the Biering-Sorensen  
117 position (prone, with the torso horizontally cantilevered over the end of a padded test bench)  
118 in order to normalize the EMG data produced by the golf swing. EMG data was collected for  
119 20 s, however, only the first 3 s of the data was used to normalize the golf swing. Manual  
120 resistance was applied by downward pressure at the scapular area, as participants maintained  
121 a constant position with their hips parallel to their legs. This position has been previously  
122 used when recording MVC EMG data from the ES muscle.<sup>18,19</sup>

#### 123 **Practice Session**

124 After a 10 minute golf specific warm-up routine, participants performed 5 maximal  
125 golf shots using the Taylormade 7-iron (Taylormade, Basingstoke, UK) and Titleist Pro-V1  
126 golf balls (Titleist, Cambridgeshire, UK). EMG data was collected from the T8, L1 and L5  
127 areas of the ES muscle on the lead and trail sides during the 5 maximal golf shots. CHS, BS  
128 and ACD were also calculated during these golf shots. After completion, participants then  
129 completed a practice session, hitting 50 maximal golf shots with the 7-iron and 50 maximal  
130 golf shots with the Taylormade driver (Taylormade, Basingstoke, UK). After the practice  
131 session, participants again hit 5 maximal golf shots with the 7-iron (Figure 1a). Before hitting  
132 shots, participants were advised to take into consideration their average distance when using  
133 the 7-iron and driver.<sup>31</sup>

134 During each golf shot, motion analysis and EMG data were recorded. All golf shots  
135 in the session were hit at a rate of one shot every 30 s. During a pilot study, golfers stated that  
136 this was a comfortable pace to perform the golf shots. To enable all golf shots to be hit safely,  
137 shots were hit from an artificial golf mat (Longridge, United Kingdom), which was placed in  
138 the centre of the laboratory, towards an enclosed golf net (Sports Net Company, United  
139 Kingdom) located 2m from the golf mat.

#### 140 **Video Data Recording**

141 For video analysis purposes, an 8-camera Vicon Bonita (Oxford Metrics Ltd, United  
142 Kingdom) Motion Analysis System operating at 250 Hz positioned around the golfer was  
143 used. This video data was synchronized with the EMG data to assess the 5 phases of the golf  
144 swing.<sup>10</sup> These 5 phases are defined in Figure 2 and are commonly used during the analysis  
145 of the golf swing.<sup>10</sup> In order to determine the 5 phases of the golf swing, the 7-iron had 4  
146 retro-reflective markers attached to the club. These markers were placed on the base of the  
147 grip, halfway down the club, the hosel of the club, and the club head.<sup>32</sup>

#### 148 **Performance Measurements**

149 In order to calculate performance variables, the Voice Caddie Swing Launch Monitor  
150 SC 100 GPS (La Mirada, CA, USA) was used. The Launch Monitor calculated CHS, BS and  
151 ACD of the golf shot. These three variables were previously validated in-house against the  
152 TrackmanTM III Golf Swing and Ball Flight Analysis System (Brighton, MI, USA). The  
153 CHS and BS were also validated against the Vicon Nexus Bonita Motion Analysis System.

#### 154 **EMG Data Analysis**

155 All of the EMG data was recorded at 1000 Hz and filtered at 15–500 Hz. The activity  
156 patterns were assessed every 20 ms.<sup>6</sup> The first 5 and final 5 maximal golf shots performed



157 with the 7-iron were analysed using RMS EMG to assess muscle fatigue during the golf  
158 swing. The values for each of the 5 phases of the golf swing<sup>10</sup> were normalized against the  
159 first 3 s of the pre-practice session MVC in order to calculate a muscle activation percentage  
160 (Figure 1b). The muscle activation percentages from the first 5 and final 5 golf shots were  
161 averaged within and between participants. Means and standard deviations (SD) were  
162 calculated for the T8, L1 and L5 regions of the ES muscle during the 5 phases of the golf  
163 swing.<sup>33</sup>

164 EMG data collected during the 20 s MVC pre and post practice session for each  
165 participant was used to assess muscle fatigue in the T8, L1 and L5 sites of the ES muscle.  
166 Fatigue was assessed by comparing the MDF and RMS signal from the MVC (Figure 1b).  
167 The initial MDF (mean of the first 5 s) and the end MDF (mean of the last 5 s) was used to  
168 assess muscular fatigue.<sup>34</sup> The same procedure was also used for RMS. Fatigue of the EMG  
169 signal was determined when the RMS of the EMG signal increased over time and when the  
170 MDF of the EMG signal decreased over time with respect to the initial and end measured  
171 time points.

## 172 **Statistical Analysis**

173 Normal distribution for all variables was assessed using the Shapiro-Wilk test.<sup>35</sup> If  
174 normal distribution was not granted, a log transformation was conducted on the specific data  
175 sets. Following this, a paired T-Test was used to determine significant differences, if any,  
176 between muscle activity before and after the golf practice session. A paired T-Test was used  
177 to determine changes in performance measures between the 5 maximum shots using the 7-  
178 iron before and after the golf practice session. EMG data from the MVC before and after the  
179 practice session was also analysed for statistical significance using a paired T-Test. For data  
180 that was not normally distributed after the log transfer (lead T8: acceleration phase), a Mann-

181 Whitney U test was performed. All calculations were performed on SPSS (version 22) and  
182 Microsoft Excel (version 2010), and  $P < .05$  was considered significant.

### 183 **Results**

184 No significant differences in muscle activation levels from the T8, L1 and L5 on the  
185 lead and trail sides of the ES muscle were displayed during the (1) backswing, (2) forward  
186 swing, (3) acceleration, (4) early follow-through phase and (5) late follow-through phase of  
187 the golf swing when comparing the first 5 maximal golf shots with the 7-iron and final 5  
188 maximal golf shots with the 7-iron ( $P > .05$ ) (Figure 3).

189 No significant changes were displayed in CHS after the golf practice session in  
190 comparison to the swings performed before the practice session when using the 7-iron ( $P >$   
191  $.05$ ). On average participants CHS was  $133.87 \pm 13.62$  at the start of the golf practice  
192 compared to  $132.99 \pm 14.69$  at the end of the golf practice session (Table 1).

193 No significant changes were displayed in BS after the golf practice session in  
194 comparison to the swings performed before the practice session when using the 7-iron ( $P >$   
195  $.05$ ). On average participants BS was  $168.83 \pm 20.31$  at the start of the golf practice compared  
196 to  $168.43 \pm 22.16$  at the end of the golf practice session (Table 1).

197 No significant changes were displayed in ACD of the golf shot after the golf practice  
198 session in comparison to the swings performed before the practice session when using the 7-  
199 iron ( $P > .05$ ). On average participants ACD was  $128.17 \pm 21.60$  at the start of the golf  
200 practice, compared to  $127.11 \pm 22.98$  at the end of the golf practice session (Table 1).

201 The ES lead L1, trail T8, trail L1 and trail L5 EMG MDF significantly reduced during  
202 the Biering-Sorensen position MVC after the practice session in comparison to the MVC at  
203 the beginning of the testing session ( $P < .05$ ). Whereas the RMS significantly increased at

204 these regions of the ES muscle. No significant differences in EMG MDF and RMS were  
205 displayed in the ES muscle lateral to the lead T8 and lead L5 of the spinous process after the  
206 practice session ( $P > .05$ ).

## 207 **Discussion**

208 The aim of this study was to describe the surface EMG activity of the thoracic and  
209 lumbar regions of the ES muscle before and after the golf practice session, and to investigate  
210 the changes, if any, in MDF and RMS before and after the golf practise session. The current  
211 study also aimed to investigate the changes, if any, in CHS, BS and ACD when performing  
212 the golf practice session.

213 The results of the current study support the hypothesis that golfers display signs of  
214 fatigue in the thoracic and lumbar ES muscle after the performance of a practice session.  
215 However, this muscular fatigue within the ES muscle was only observed during the MVC  
216 performed at the end of the testing session and not during the performance of the golf swings.  
217 Furthermore, the results showed that the golf practice session did not have any effect on the  
218 CHS, BS and ACD of the golf shot when comparing the golf swings before and after the golf  
219 practice session.

220 Measuring changes in the EMG power spectrum is the most common way to assess  
221 muscular fatigue. Muscle fatigue is defined as a reduction in maximum contractile force in  
222 the a muscle.<sup>36</sup> Localised muscular fatigue can be analysed using surface EMG measurements  
223 of MDF.<sup>37</sup> Suggestions have been made that MDF should only be used when the exercise  
224 being performed is of high stability.<sup>38</sup> These recommendations are a result of the recruitment  
225 and de-recruitment of different motor units during dynamic movements which, therefore,  
226 reduce the stability of the EMG signal. Due to these recommendations, the MVC exercise

227 was analysed with MDF and RMS filtering. As the golf swing is a dynamic movement, only  
228 RMS filtering was employed for the assessment of the golf swing.

229 Results from the current study displayed no significant change in RMS EMG muscle  
230 activity when comparing golf swings before and after the golf practice session. These results  
231 suggest that no muscular fatigue is evident within the thoracic and lumbar ES muscle when  
232 performing the golf practice session. As previously discussed, limited research has been  
233 conducted on muscular fatigue during the golf swing. Horton and associates investigated  
234 muscular fatigue of the abdominal muscles during a golf practice session and found that the  
235 golf practice session did not influence abdominal muscle fatigue during the golf swing.<sup>3</sup>  
236 Whilst these results are not directly comparable with the current research, the two studies do  
237 suggest that muscular fatigue is not evident in the trunk area throughout the golf swing when  
238 performing multiple golf swings. Horton et al<sup>3</sup> also found that the golf practice session did  
239 not significantly change BS, which further suggests that no muscle fatigue signs were  
240 evident. These results are directly comparable to the current research, as it was found that BS  
241 did not significantly change after the completion of the golf practice session. It would seem  
242 likely that BS would decrease if muscular fatigue was observed. The current study also  
243 displayed no significant changes in CHS and ACD of the golf shot after the completion of the  
244 practice session. These results further demonstrate muscular fatigue was not observed in the  
245 thoracic and lumbar ES muscle during the golf practice session.

246 Results from the current study suggest that muscular fatigue is evident in the thoracic  
247 and lumbar regions of the ES muscle during the MVC. On completion of the golf practice  
248 session, the MDF for the trail side of the thoracic and lumbar ES muscle significantly  
249 reduced, whereas the RMS significantly increased, suggesting muscular fatigue is evident.  
250 These results may suggest that the golfers are mechanically efficient throughout the golf  
251 swing, however, when performing the MVC, the ES muscle begins to fatigue. Additionally,

252 since the trail side of the thoracic and ES muscle is highly active throughout the (2) forward  
253 swing and (3) acceleration phases of the golf swing, this might have caused the muscle to  
254 fatigue at a greater rate during the MVC. Furthermore, this may have been a result of the ES  
255 muscle having to contract at a greater level during the MVC in comparison to the golf swing.  
256 To date, there is limited data surrounding the influence of fatigue on the ES muscle.

257 Caldwell et al<sup>28</sup> investigated three regions of the lumbar ES muscle before and after a  
258 rowing session. This research found that, MDF significantly decreased during the MVC after  
259 the rowing session, which is in agreement with the current study. It must be acknowledged,  
260 however, that the rowing was performed at a higher intensity than the golf swing. As  
261 previously discussed, Horton et al<sup>3</sup> assessed abdominal muscular fatigue during the golf  
262 swing. Similar to the current study, these researchers also investigated muscular fatigue after  
263 the golf practice as well as during the session. Muscular fatigue after the golf session was  
264 assessed through a sub-MVC, however, Horton and colleagues reported no significant change  
265 in MDF or RMS when the sub-MVC was performed before and after the golf practice  
266 session. These conflicting results may suggest that the ES muscle fatigues at a greater rate  
267 than the abdominal muscles during the golf swing, especially when counteracting the effects  
268 of gravity during the (2) forward swing phase.<sup>13</sup>

269 It is important to consider the limitations of the current study when interpreting the  
270 results. First, the test was conducted in a laboratory, therefore hitting surface, target lines and  
271 weather conditions could not be emulated. Secondly, the current study mimicked a golf  
272 practice session, however, results may be different when playing a round of golf due to other  
273 variables such as: walking, lifting and carrying golf clubs, number of shots hit, and number of  
274 practice swings performed. These factors could potentially increase muscle fatigue in the ES,  
275 therefore, further investigation should be considered.

276 In summary, the results of this study showed that there were no significant differences  
277 in RMS EMG of the thoracic and lumbar ES muscle when the golf swings were performed  
278 before the golf practice session compared to the after the session. Furthermore, the practice  
279 session had no effect on CHS, BS and ACD of the golf shot. However, the thoracic and  
280 lumbar ES muscle displayed signs of fatigue, especially in the trail side, when performing the  
281 MVC exercise after the practice session was completed. The current study may assist  
282 clinicians in the prevention of injury to the lower back muscles during golf play and also  
283 suggests that golfers are required to have good physical conditioning with regards to the ES  
284 muscle.

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430 **Table 1** Mean and SD at the start and end of the golf practice session when using the 7-iron.

Participant	Start			End		
	Absolute Carry Distance (m)	Club Head Speed (km/h)	Ball Speed (km/h)	Absolute Carry Distance (m)	Club Head Speed (km/h)	Ball Speed (km/h)
A	123.60 ± 3.91	131.80 ± 5.76	180.00 ± 3.24	125.80 ± 6.53	132.60 ± 7.50	180.80 ± 5.26
B	133.60 ± 4.51	139.40 ± 8.26	184.40 ± 6.88	133.60 ± 4.39	140.60 ± 9.32	184.80 ± 5.97
C	142.20 ± 5.36	133.40 ± 2.88	179.40 ± 5.03	144.60 ± 1.95	134.60 ± 1.52	181.80 ± 1.64
D	141.80 ± 7.82	140.20 ± 4.44	179.40 ± 7.33	143.00 ± 2.74	141.80 ± 4.49	180.60 ± 2.30
E	111.60 ± 9.40	125.20 ± 6.38	151.60 ± 8.47	118.20 ± 14.18	130.20 ± 6.22	157.40 ± 12.93
F	131.40 ± 14.99	138.80 ± 3.70	169.60 ± 13.43	108.20 ± 10.13	127.00 ± 4.24	148.80 ± 8.87
G	154.20 ± 5.85	153.20 ± 1.30	191.40 ± 6.02	152.40 ± 10.78	150.20 ± 3.56	190.20 ± 11.17
H	120.60 ± 16.35	128.60 ± 3.13	159.80 ± 14.20	112.80 ± 8.17	121.20 ± 3.42	152.40 ± 7.30
I	119.60 ± 8.79	122.00 ± 4.74	158.60 ± 8.20	121.40 ± 10.01	125.80 ± 7.76	160.20 ± 8.93
J	72.30 ± 13.58	101.30 ± 12.10	116.60 ± 12.42	71.00 ± 3.83	96.20 ± 2.63	115.20 ± 3.40
K	113.20 ± 7.69	125.00 ± 8.60	152.80 ± 6.83	108.80 ± 8.44	123.80 ± 8.23	149.40 ± 7.40
L	151.20 ± 8.58	155.20 ± 8.23	189.20 ± 7.82	147.20 ± 5.89	155.80 ± 8.11	187.00 ± 7.51
M	153.80 ± 6.10	143.60 ± 3.85	187.80 ± 12.33	158.40 ± 5.45	146.20 ± 3.27	196.20 ± 7.44
N	125.20 ± 11.12	136.40 ± 4.51	163.20 ± 11.43	135.80 ± 5.40	135.80 ± 5.50	173.20 ± 4.97

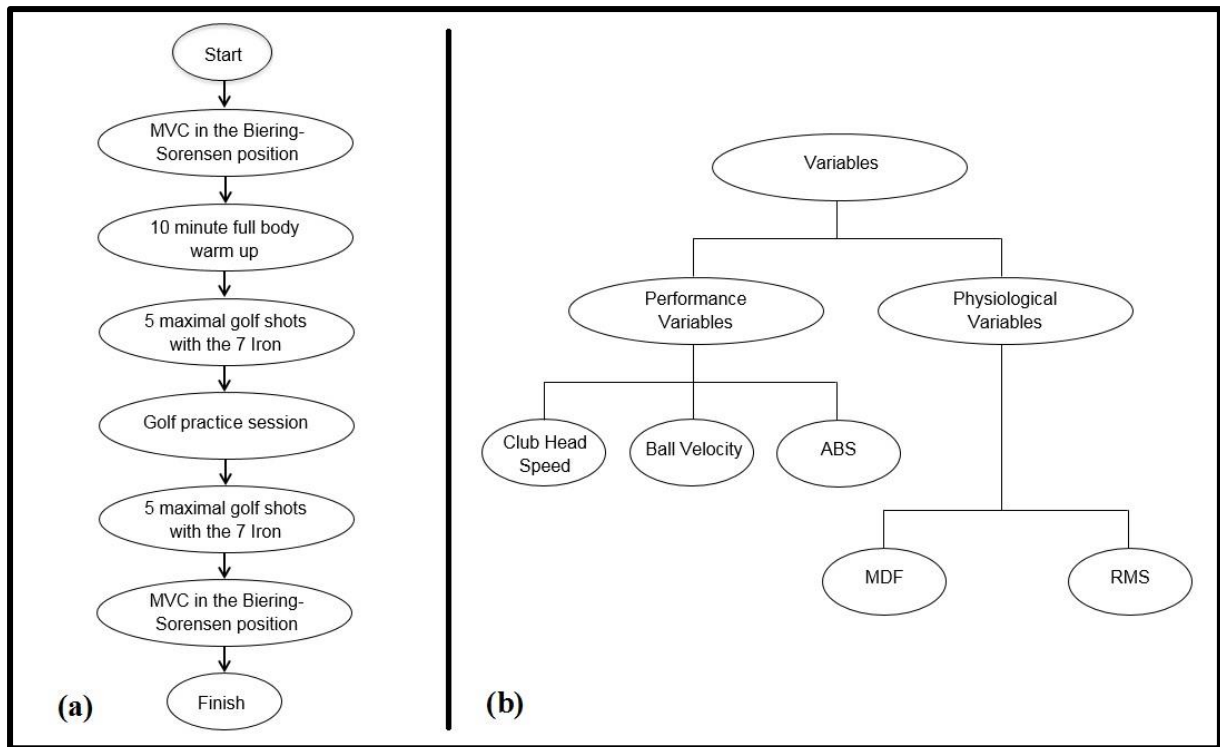
## Figure Captions

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**Figure 1** – (a) experimental procedure, (b) variables compared within the study. Absolute carry distance (ACD), median frequency (MDF) and root mean squared (RMS).

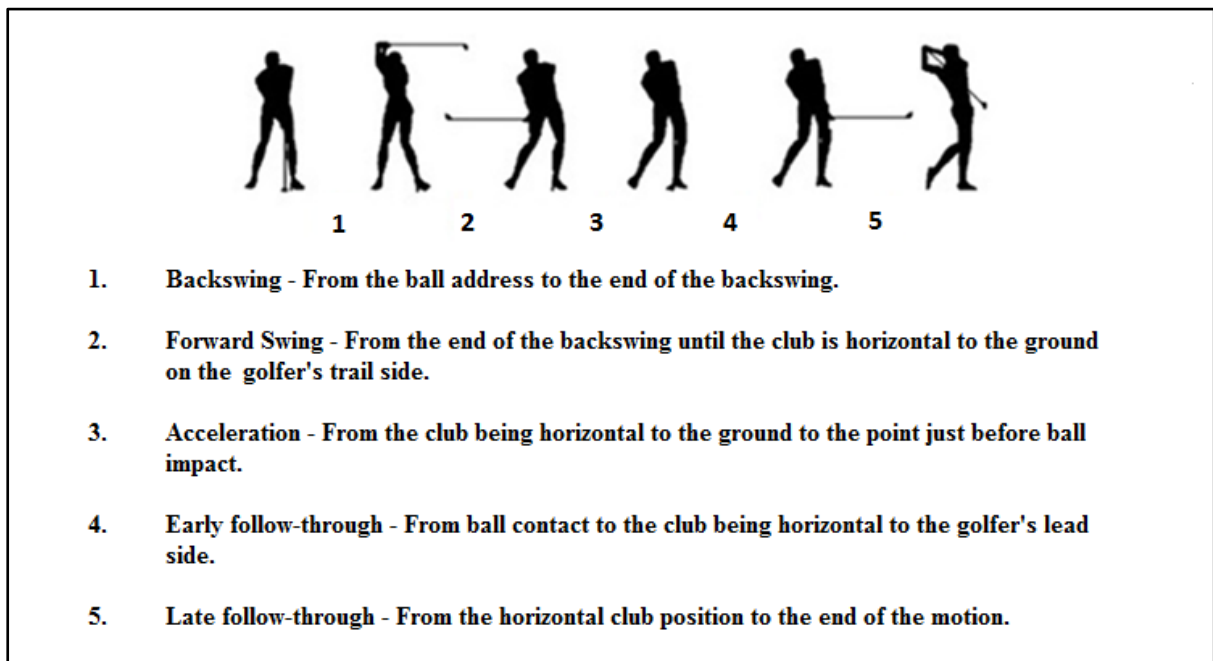
**Figure 2** – Silhouette description of the phases of the golf swing.

**Figure 3** – Thoracic and lumbar erector spinae muscle activation (%) throughout the golf swing. Phase 1 (backswing), phase 2 (forward swing), phase 3 (acceleration), phase 4 (early follow-through), phase 5 (late follow-through). Maximum voluntary contraction (MVC).



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461 **Figure 1** – (a) experimental procedure, (b) variables compared within the study. Absolute  
 462 carry distance (ACD), median frequency (MDF) and root mean squared (RMS).



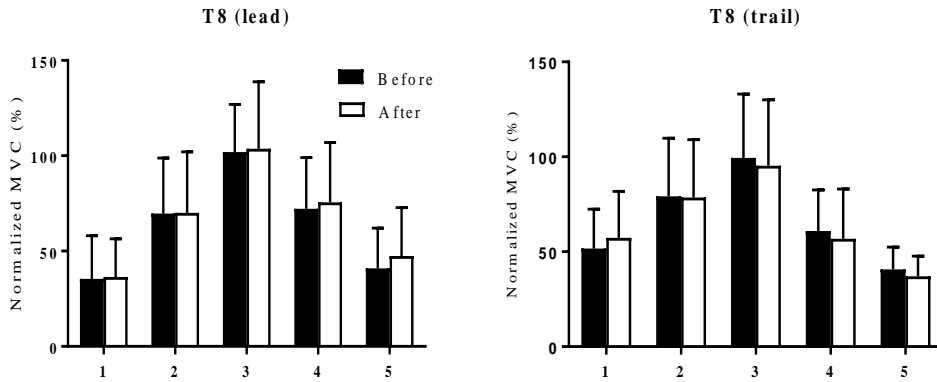
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464 **Figure 2** – Silhouette description of the phases of the golf swing.

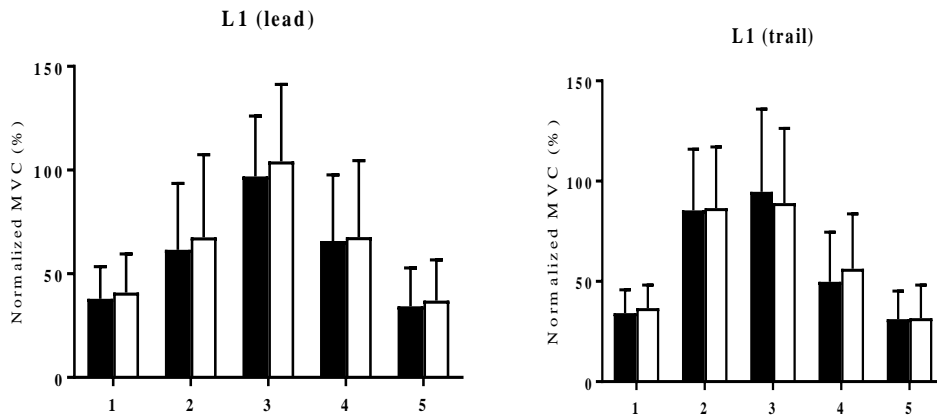
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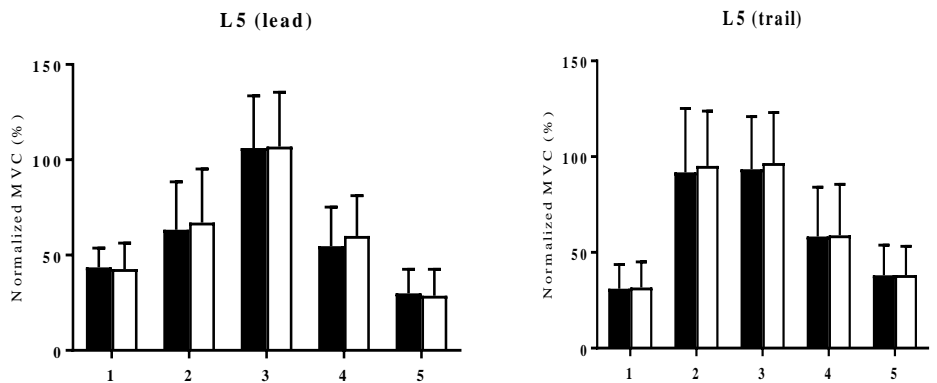
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471 **Figure 3** – Thoracic and lumbar erector spinae muscle activation (%) throughout the golf  
472 swing. Phase 1 (backswing), phase 2 (forward swing), phase 3 (acceleration), phase 4 (early  
473 follow-through), phase 5 (late follow-through). Maximum voluntary contraction (MVC).

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