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

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Running Title: *Erector Spinae Muscle Activation during Golfing*

Abstract

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

Keywords: *Muscle Fatigue, EMG, Performance*

Word Count: 3599

Introduction

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

EMG techniques have been used to analyse muscle activity in the upper and lower body during the golf swing.[3,6–14] These studies have assessed shoulder, forearm, upper and lower back, trunk and lower limb muscles and have mainly focused their attentions on predicting muscle activation levels in order to reduce injury risks and increase performance in the sport.[6,14,15]

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

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

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

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

Methods

Participants

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

EMG Procedure

EMG activity was recorded using 12 surface electrodes (AMBU, Cambridgeshire, UK) and a set of 6 Surface EMG Transmitters (Myon 320, Schwarzenberg, Switzerland). In order to reduce impedance at the interface between the skin and the surface electrode, the participant's skin was prepared removing hair from the tested area, followed by skin abrasion and alcohol cleaning. Pairs of surface EMG electrodes were attached to the skin no more than 20mm apart (centre to centre) along the expected muscle direction of the lead (left side for right handed golfers) and trail (right side for right handed golfers) sides of the thoracic and lumbar ES muscle. Specifically, electrodes were placed 30 mm lateral to the spinous process of the eighth thoracic vertebrae (T8)[26,27] and 30 mm lateral to the first lumbar vertebrae (L1).[28,29] For the lower lumber region of the ES muscle, electrodes were placed on and aligned with a line from caudal tip posterior spina iliaca superior to the interspace between L1 and L2 interspace at the level of the fifth lumbar vertebrae (L5). [29,30]

EMG Normalizing Procedure

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

Practice Session

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

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

Video Data Recording

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

Performance Measurements

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

EMG Data Analysis

All of the EMG data was recorded at 1000 Hz and filtered at 15–500 Hz. The activity patterns were assessed every 20 ms.[6] The first 5 and final 5 maximal golf shots performed with the 7-iron were analysed using RMS EMG to assess muscle fatigue during the golf swing. The values for each of the 5 phases of the golf swing[10] were normalized against the first 3 s of the pre-practice session MVC in order to calculate a muscle activation percentage (Figure 1b). The muscle activation percentages from the first 5 and final 5 golf shots were averaged within and between participants. Means and standard deviations (SD) were calculated for the T8, L1 and L5 regions of the ES muscle during the 5 phases of the golf swing.[33]

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

Statistical Analysis

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

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

Results

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

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

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

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

The ES lead L1, trail T8, trail L1 and trail L5 EMG MDF significantly reduced during the Biering-Sorensen position MVC after the practice session in comparison to the MVC at the beginning of the testing session ($P < .05$). Whereas the RMS significantly increased at these regions of the ES muscle. No significant differences in EMG MDF and RMS were displayed in the ES muscle lateral to the lead T8 and lead L5 of the spinous process after the practice session ($P > .05$).

Discussion

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

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

Measuring changes in the EMG power spectrum is the most common way to assess muscular fatigue. Muscle fatigue is defined as a reduction in maximum contractile force in the a muscle.[36] Localised muscular fatigue can be analysed using surface EMG measurements of MDF.[37] Suggestions have been made that MDF should only be used when the exercise being performed is of high stability.[38] These recommendations are a result of the recruitment and de-recruitment of different motor units during dynamic movements which, therefore, reduce the stability of the EMG signal. Due to these recommendations, the MVC exercise was analysed with MDF and RMS filtering. As the golf swing is a dynamic movement, only RMS filtering was employed for the assessment of the golf swing.

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

Results from the current study suggest that muscular fatigue is evident in the thoracic and lumbar regions of the ES muscle during the MVC. On completion of the golf practice session, the MDF for the trail side of the thoracic and lumbar ES muscle significantly reduced, whereas the RMS significantly increased, suggesting muscular fatigue is evident. These results may suggest that the golfers are mechanically efficient throughout the golf swing, however, when performing the MVC, the ES muscle begins to fatigue. Additionally, since the trail side of the thoracic and ES muscle is highly active throughout the (2) forward swing and (3) acceleration phases of the golf swing, this might have caused the muscle to fatigue at a greater rate during the MVC. Furthermore, this may have been a result of the ES muscle having to contract at a greater level during the MVC in comparison to the golf swing. To date, there is limited data surrounding the influence of fatigue on the ES muscle.

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

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

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

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Tables

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

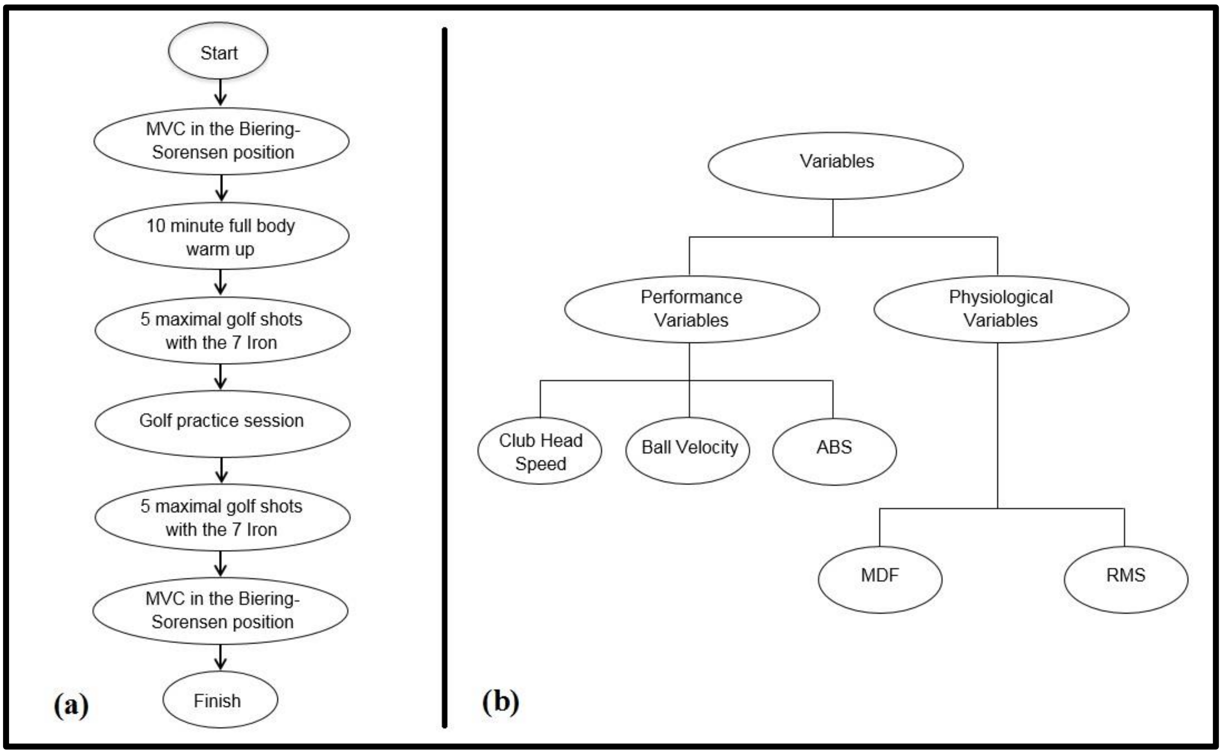
Figure Captions

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).

Figures



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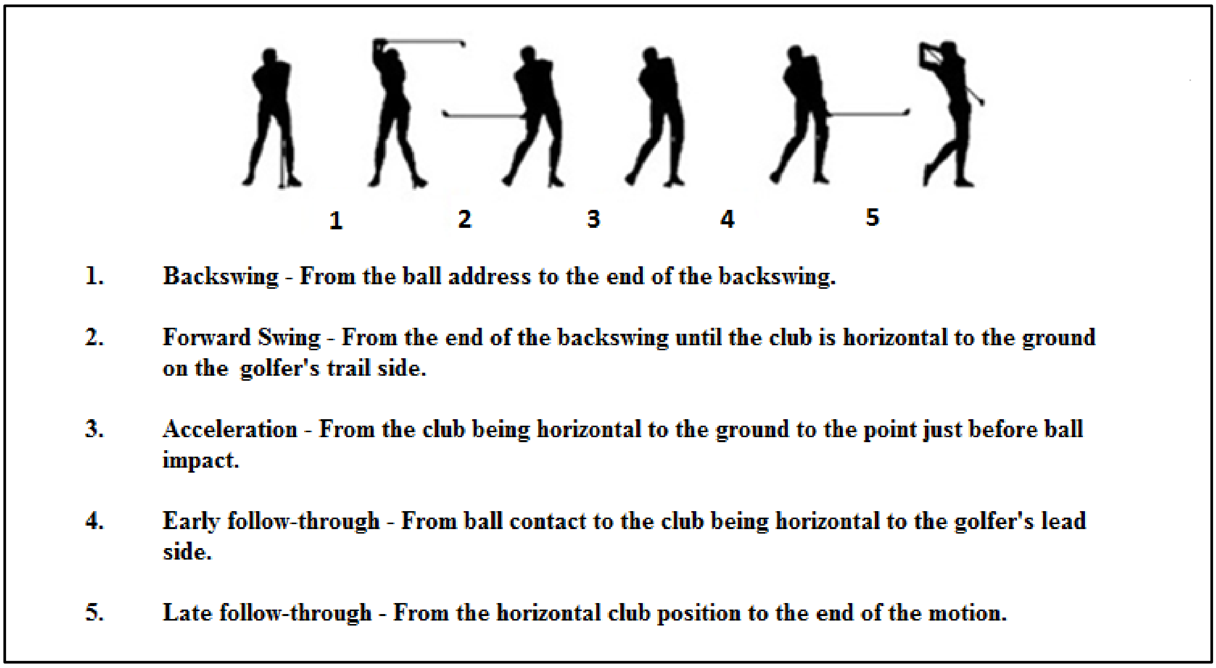

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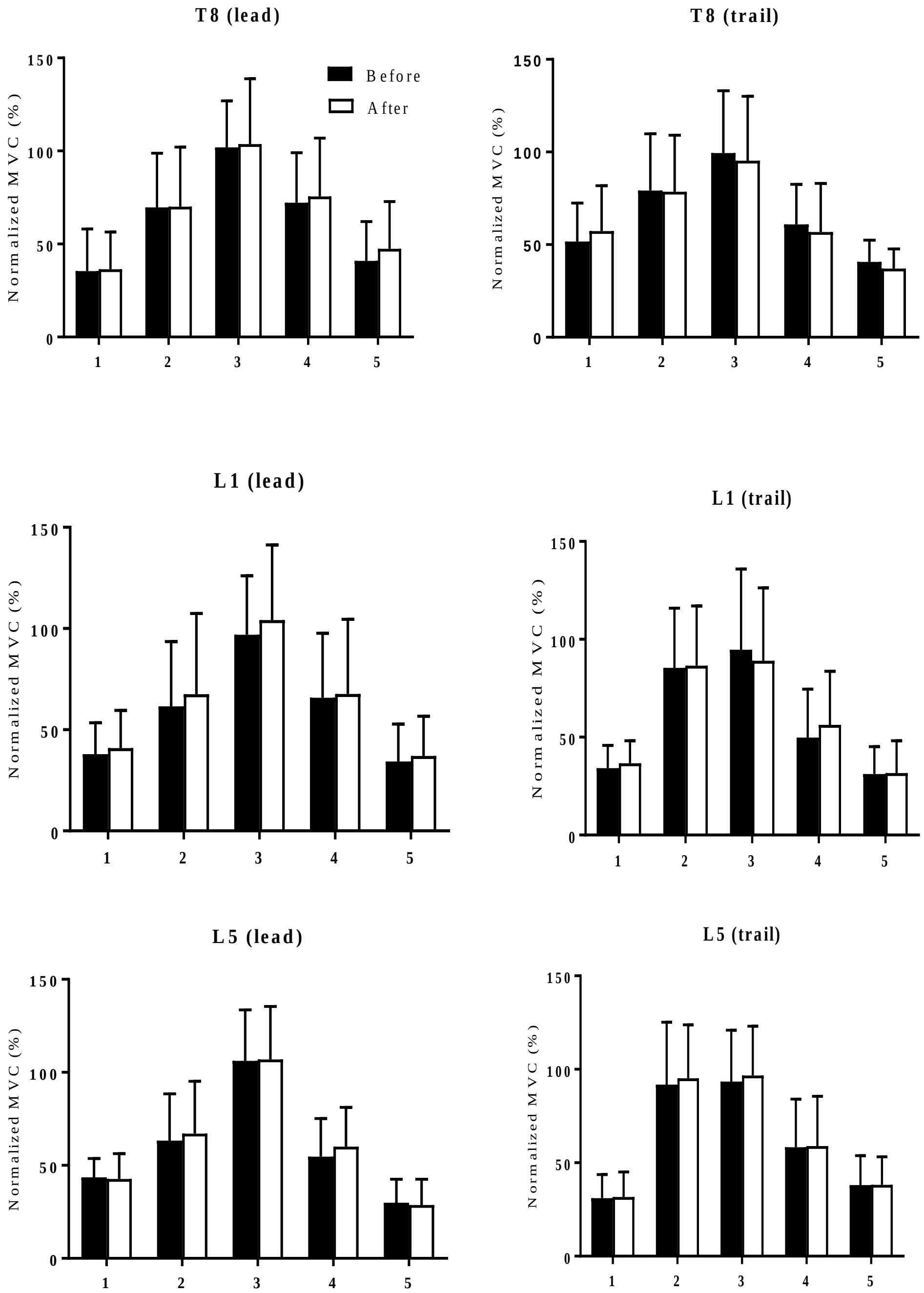

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