A PRELIMINARY STUDY: EXPLORING THE MUSCULAR CHANGES BETWEEN PARTIAL AND FULL SHOTS DURING THE DOWNSWING IN GOLF UTILISING STATISTICAL PARAMETRIC MAPPING

Sam Todd[1], Jon Swain[1] and Mathew Brown[1]

Section of Sport and Exercise Science, Canterbury Christ Church University, Canterbury, United Kingdom[1]

The purpose of this study was to assess the feasibility of using Statistical Parametric Mapping (SPM) data analysis techniques on golf swing electromyographic (EMG) data and to explore any muscular changes that might occur between full and partial golf shots. Three male golfers completed the testing. The results of the ANOVA suggest that two muscles show a significant decrease in muscle activation between the shot conditions, Right Medial Gastrocnemius (RMG)(p<0.001) and Right Rectus Abdominus (RRA) (p<0.001). The post-hoc analysis suggests that RMG and RRA both decrease activation to perform partial shots. The results suggest that SPM analysis is a useful tool for golf swing research and that specific muscles might show activation changes associated with reducing shot distance.

KEYWORDS: Golf, EMG, SPM.

INTRODUCTION: It has been shown that kinetics and kinematics change to allow the golfer to perform partial golf shots (Todd, Wiles, Coleman & Brown, 2018). When analysing golf data, traditionally researchers have identified regions of interest in the downswing based on either temporal data (final 50ms) or kinematic phases of the club/golfer (arms horizontal), which are based on golf coaching practice rather than empirical data. Recently the use of Statistical Parametric Mapping (SPM) for biomechanical analysis has been validated using ANOVAs (Pataky, Vanrenterghem & Robinson, 2015); therefore, it should be possible to utilise the SPM methods to assess the entire downswing as a whole and identify regions of interest during the downswing that may be important for performing partial golf swings. SPM disregards comparatively little data relative to traditional scalar analysis; therefore the study aimed to ascertain if SPM data analysis techniques can be utilised for biomechanical golf data and whether muscle activations significantly change when performing partial shots when compared to a full swing shot with a pitching wedge. The tested null hypothesis was that %MVC values for muscles during the downswing of a partial shot are not different from the values when performing to a full shot distance.

METHODS: The University Ethics Committee approved the study protocol, and all the procedures were carried out in accordance with the Declaration of Helsinki. Three male participants (29 ± 7 years, 1.85m ± 0.02m, 81kg ± 7kg, 8 ± 9 UK Council of National Golf Unions (CONGU) handicap) took part in the study.

The muscles selected for the study aimed to analyse the full body during the golf swing. To be able to measure all the muscles needed required completing the analysis in two parts. Part one focused on the anterior upper body muscles bilaterally including; Pectoralis Major, External Oblique, Rectus Abdominus, Wrist Flexor group and Biceps Brachii. Part two focused on posterior upper body muscles and lower body muscles bilaterally including; Latissimus Dorsi, Erector Spinae, Bicep Femoris and Vastus Lateralis. Right, Medial and Lateral Gastrocnemius were also measured in part two of the testing.

Before completing their golf swings, the participants were required to complete 3-second isometric Maximum Voluntary Contractions (MVCs) for each muscle. Participants were required to perform 5 ‘Full shots’ to obtain their full shot carry distance, collected using a Flightscope X2 doppler radar (EDH Ltd, South Africa) with a pitching wedge. Using the full shot carry distance, each participant had individualised shot distance bands calculated for all conditions (100% ± 5%, 80% ± 5% and 60% ± 5%).

Each condition required the participant to perform 5 shots whereby their carry distance fell between the calculated distance band within a ±5% error. During which, the EMG sensors (Noaraxon, USA) measured muscle activation of each muscle at 1500Hz. To allow for the identification of the phases of the golf swing an accelerometer was placed on the club shaft just above the clubhead (Phase identification was formulated using a pilot study using a high-speed camera synced to the accelerometer).

SPM was used to compare muscle activation for each of the shot distances. An SPM one-way repeated-measures ANOVA was used to compare the muscle activations for each muscle during each carry distance condition (α=0.05). At each time node, a scalar output statistic was calculated, SPM{F}. However, to test the null hypothesis a critical threshold was calculated at which only α % (5%) of smooth random curves would be expected to transverse (Friston, Ashburner, Kiebel, Nichols & Penny, 2007). SPM uses Random Field Theory to calculate *p*-values at each cluster which indicate the probability that a random field process could have produced the supra-threshold clusters with the same temporal smoothness. All SPM analyses were implemented using an adapted spm1d code (v0.4.3, spm1d.org) in Spyder python development environment (v3.3.6, spyder-ide.org) utilising Python environment (v3.7.4, python.org).

Post-hoc analysis involved the use of two-sample t-test, with the critical *p*-value corrected using a Bonferroni correction (*p*-Crit-Bonf). The *p*-Crit-Bonf = 0.0016694 for this analysis. T-tests were then completed on any muscles with significantly different results.

RESULTS: Of the 20 muscles analysed, our preliminary dataset found two muscles (RMG and RRA) that showed a significant difference between the three shot conditions, which are presented below in figures 1 and 2. The other 18 showed no supra-clusters that crossed the critical threshold value. The mean muscle activations were highly similar for most of the downswing phase for the RMG. However, one supra-threshold cluster (44.722% - 47.945%) (Figure 1a) that exceeded the critical threshold of 34.106, indicating there was a significant difference between partial shot carry distances (Figure 1b). The exact probability that a supra-threshold cluster of this size would be observed in repeated random samplings was *p*<0.001.

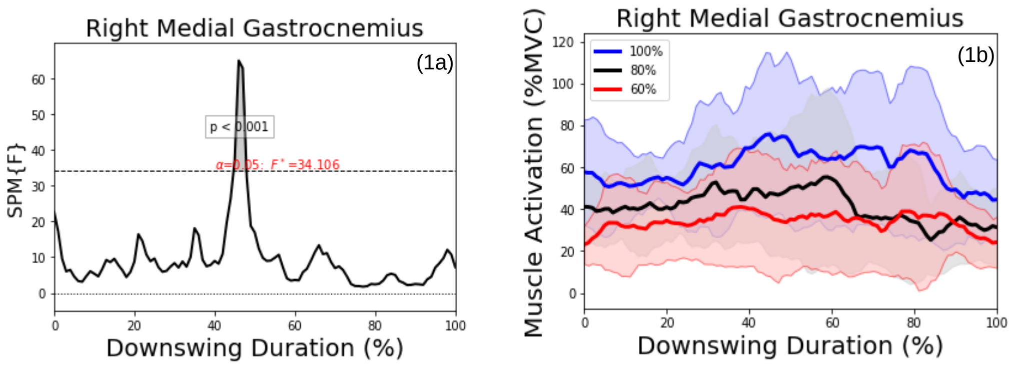

Figure 1a) The repeated measures ANOVA test statistics SPM {F}. b) Mean %MVC values during the downswing for each shot carry distance.

The RRA had one supra-threshold cluster (23.051% - 30.871%) (Figure 2a) that exceeded the critical threshold of 31.355, indicating that there was a significant difference between the partial shot carry distances (Figure 2b). The exact probability that a supra-threshold cluster of this size would be observed in repeated random samplings was *p*<0.001.

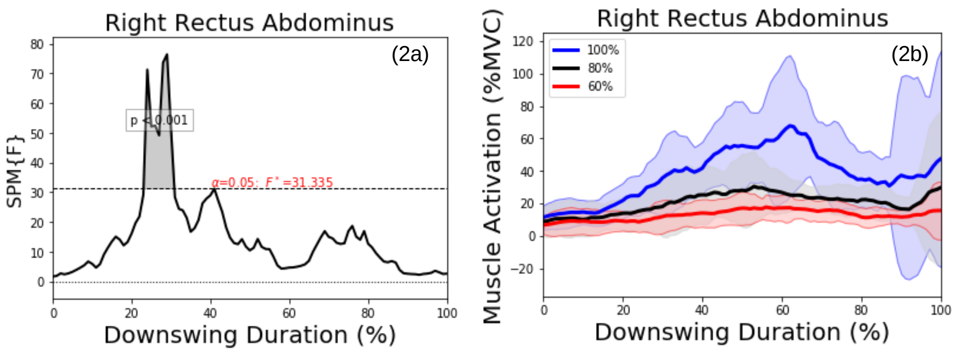

Figure 2a) The repeated measures ANOVA test statistics SPM {F}. b) Mean %MVC values during the downswing for each shot carry distance.

The post-hoc analysis was then completed for the two muscles, comparing each shot condition. The results of the analysis below, only showing significant t-tests, Figures 3 & 4 suggest that there are differences between the three conditions suggesting that RMG and RRA activation reduces between 100% and 60%.

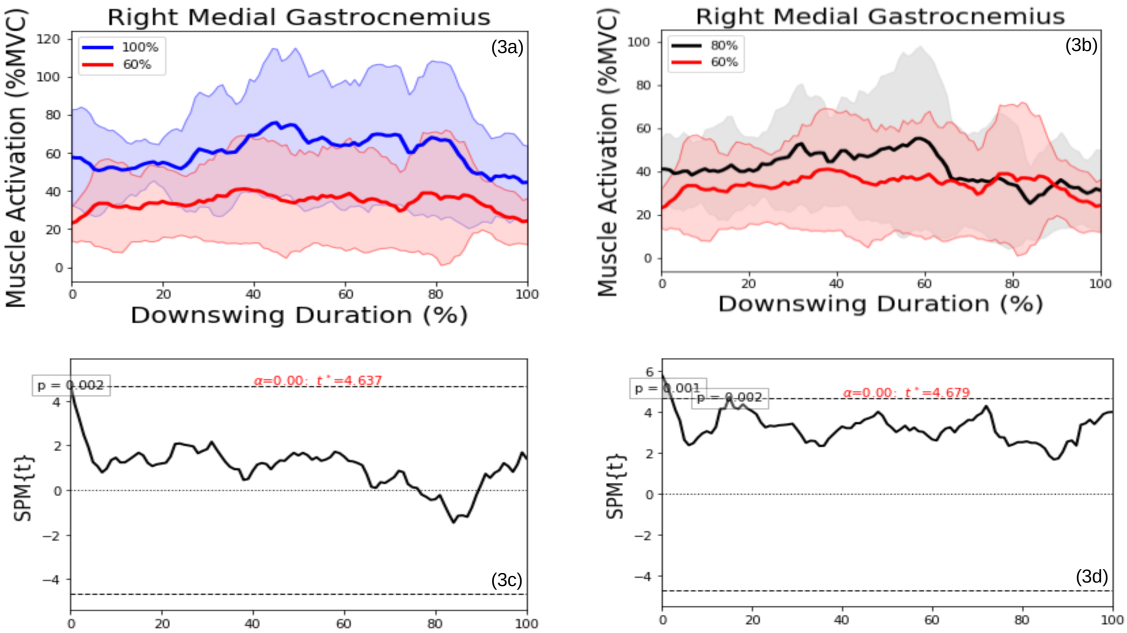

Figure 3a&b) Mean %MVC for RMG during the downswing. c&d) T-test statistics during the downswing with supra-clusters associated a p-value.

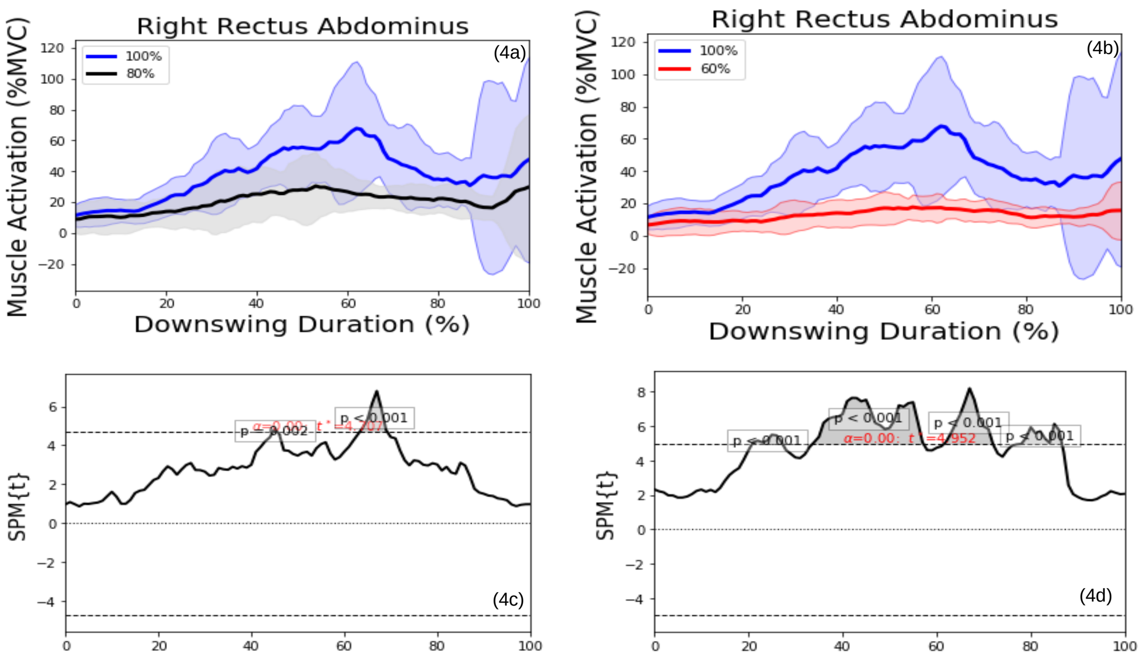

Figure 4a&b) Mean %MVC for RRA during the downswing. c&d) T-test statistics during the downswing with supra-clusters associated a p-value.

DISCUSSION: The current study supports the use of SPM analysis and is appropriate to use to analyse golf swing specific data, as the cyclical, repetitive nature of the golf swing allows for relatively easy transformation for SPM analysis. It must be said, however, that there is a limitation with the use of SPM analysis. Firstly, Post-Hoc analysis using Bonferroni corrections has yet to be validated; therefore, post-hoc results are not as robust as current post-hoc methods on discrete data sets. However, due to the reduction in selection bias, associated with researchers selecting the criteria for the discrete variables such as peaks and specific temporal averages, the fact that SPM analysis eliminates that bias is beneficial for its use.

Regarding the second aim of the study, given the small dataset one is unable to be too confident in generalisations; however, the results for two of the muscles (RMG and RRA) show apparent reductions between the muscle activation patterns during the downswing between each carry distance condition, which follows on from work by Todd *et al.* (2018). The RRA shows the largest significant change in muscle activation from full to partial shots (100v60) up to a reduction of 40% activation for a large portion of the downswing phase (20%-90%). The data suggests that one of the mediators of reducing shot distance is limiting the activation of right rectus abdominus, this could be the golfer actively attempting to reduce the speed generation of the golf club during this phase. As the RRA is a major muscle in hip rotation (Loock, Grace and Semple, 2013), it would suggest that hip rotation could be a key factor in performing partial shots. This indicates that there is definite scope for further analysis, and the SPM analysis technique will help to identify any changes, which can be used to be more specific regarding the exact temporal location whereby changes occur during the downswing, which has the potential to inform coaching of partial shots.

CONCLUSION: This study has shown that SPM analysis can be utilised to analyse golf performance. Limited analysis indicates that a reduction in activation in RMG and the RRA have roles to play in the performing of partial shots. Having determined the suitability of SPM for the goal swing, future research will increase sample size and diversity in the participant sample, to determine strategies employed across, ability, gender and age levels.

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