Journal of Electromyography and Kinesiology 23 (2013) 1174–1182

Contents lists available at SciVerse ScienceDirect

Journal of Electromyography and Kinesiology

journal homepage: www.elsevier.com/locate/jelekin

Trunk muscle activation during golf swing: Baseline and threshold

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ARTICLE INFO

Article history:
Received 5 October 2012
Received in revised form 24 April 2013
Accepted 28 May 2013

Keywords:
EMG
Threshold
Trunk
Onset
Golf swing

ABSTRACT

There is a lack of studies regarding EMG temporal analysis during dynamic and complex motor tasks, such as golf swing. The aim of this study is to analyze the EMG onset during the golf swing, by comparing two different threshold methods. Method A threshold was determined using the baseline activity recorded between two maximum voluntary contraction (MVC). Method B threshold was calculated using the mean EMG activity for 1000 ms before the 500 ms prior to the start of the Backswing. Two different clubs were also studied. Three-way repeated measures ANOVA was used to compare methods, muscles and clubs. Two-way mixed Intraclass Correlation Coefficient (ICC) with absolute agreement was used to determine the methods reliability.

Club type usage showed no influence in onset detection. Rectus abdominis (RA) showed the higher agreement between methods. Erector spinae (ES), on the other hand, showed a very low agreement, that might be related to postural activity before the swing. External oblique (EO) is the first being activated, at 1295 ms prior impact. There is a similar activation time between right and left muscles sides, although the right EO showed better agreement between methods than left side. Therefore, the algorithms usage is task- and muscle-dependent.

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1. Introduction

Several approaches have been proposed for EMG onset detection; however there is no standardized method and its application is mainly done in motor skills with isometric contraction (Farina and Merletti, 2000), as they present better reproducibility (Lee et al., 2011). A complex motor skill such as a golf swing combines both power and precision. The purpose of the golfer is to place a ball inside a small hole with the least hits possible (Hume et al., 2005). Although it is not considered an intensive and exhausting sport, skeletal-muscle stress and demand are associated with high injury incidence (Cabri et al., 2009).

The study of onset muscle activity can provide information regarding the temporal organization and coordination of a set of muscles at use during a task (De Luca, 1997). In explosive and precise motor tasks, as throwing, the trunk muscles sequence plays an important role in the organization of the proximo-distal sequence in order to transfer energy (Hirashima et al., 2002). This mechanism leads to an increase of speed in distal segments. The movement of different body segments will depend on the motor programming of the central nervous system, which translates into a specific sequence, intensity and muscle time activation. In subjects with low back pain, the reaction time (activation to movement initiation) of abdominal muscles tends to increase as upper limb task complexity increases, due to postural organization (Hodges, 2001).

Most studies on trunk muscle EMG activity during a golf swing have focused on intensity parameters (Pink et al., 1993; Watkins et al., 1996). Only two studies have analyzed the EMG activation onset (Horton et al., 2001; Cole and Grimshaw, 2008). Both have used a threshold detection algorithm, and compared trunk muscles between symptomatic and asymptomatic golfers' lower back pain. Horton et al. (2001) used seven standard deviations (SDs) above baseline, with a 200 ms window (i.e. time interval considered for a group of samples). Although they did not find differences for the amplitude of abdominal activity between the two groups, asymptomatic subjects activated the left external oblique (EO) significantly earlier than the symptomatic, in respect to the start of the backswing. Cole and Grimshaw (2008) have set the onset at 1 SD above baseline, with a 50 ms moving window. Their results did not present significant differences between the two groups

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1050-6411/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jelekin.2013.05.007

for EO, but the erector spinae (ES) was activated significantly sooner for golfers with low back pain. The difficulty in comparing studies is related to the different algorithms criteria, which compromises the reproducibility of the results (Morey-Klapsing et al., 2004; Jöllenbeck, 2000). This is particularly evident for threshold algorithms (Staude et al., 2001).

Onset detection can be divided into two categories: visual inspection (VI) and detection algorithms (Vaisman et al., 2010; Hug, 2011). Visual inspection requires a time-consuming work and the precision of the results depends on the researcher's expertise; therefore being a subjective process (Jöllenbeck, 2000) and its use being rather paradigmatic. However, the lack of a *goldstandard* measurement used to validate the algorithms, leads to visual inspection being used to assess the precision of threshold algorithms. Algorithms Detection can be classified into threshold algorithms (Van Boxtel et al., 1993; Hodges and Bui, 1996; Jöllenbeck, 2000; Allison, 2003) and as statistically optimized algorithms (Micera et al., 1998; Staude et al., 2001), as maximum likelihood.

The usual definition of onset refers to the initial activity register of the motor units' action potentials (Solnik et al., 2010). The different phases that make up complex motor skills would require different approaches for the meaning of EMG signal. McGill et al. (2010) characterizing a double-peak intensity phenomenon in motor skills such as kicking in martial arts. This phenomenon could be associated with the muscular actions during the different phases of those tasks. For golf swinging several phases can be discriminated, such as the preparation (backswing), execution (downswing) and result (follow-through). Some authors have opted to include descriptive and qualitative movement analysis, due to activity characteristics and particular muscle actions (Hirashima et al., 2002; McGill et al., 2010).

The precision with which a certain algorithm detects the onset is influenced by the background activity level, signal-to-noise ratio activity (Hodges and Bui, 1996; Staude et al., 2001), and onset rate of signal amplitude (Allison, 2003). Hug (2011) states that threshold algorithms vary in 1, 2, and 3 SD or between 15% and 25% of the activity's maximum peak. Other threshold algorithm approaches have considered onset to be the moment in which signal voltage/intensity surpasses the confidence interval upper limit in a fixed number of samples (Van Boxtel et al., 1993). Hodges and Bui (1996) which have compared onset detection algorithms with different options of low pass filters 10, 50, 500 Hz combined with different sampling windows 10, 25, 50 ms and standard deviations 1, 2, 3 SD for different background activity levels. The most adequate combinations for cutoff frequency, sample window and SD were are 50 Hz/25 ms/3SD and 50 Hz/50 ms/1SD. This clearly demonstrated that excessive smoothing leads to loss of information, and that insufficient smoothing is associated with an onset detection delay.

Parameters knowledge on what constitutes the detection of algorithms is crucial on EMG temporal analysis. However, this analysis should not be restricted to isometric contractions. Temporal activity should take into account the dynamic motor skills phases, identifying key moments of motor coordination.

Golfers often wonder whether the swing is always the same when using different clubs. Swing phase time seems to be similar, but the club speed could be different (Egret et al, 2003), although there is a lack of knowledge on the activation timing in using different clubs.

The aim of this study is to analyze the temporal activity during the golf swing given the preparation phase (backswing) and execution phase (downswing) by comparing the use of two different baselines, activity threshold methods and visual inspection. Moreover, we intend to investigate whether or not the usage of different clubs leads to changes in the onset detection.

2. Method

2.1. Participants and task

Eight male right-handed amateur golfers (52.0 ± 7.4 years old; handicap of 15.7 ± 3.2) were instructed to perform five precision swings with pitching (<100 m) and five long range swings with iron 4 (>150 m) in an alternate sequence ($n = 80$). Before any experimental procedure, subjects were allowed to perform some repetitions, in order to enable a better adaptation to the task and to warm up. The swings were carried out on top of an artificial grass golf carpet with high absorption features. Subjects did not have any limitations for playing golf. All the procedures were explained and a consent form was signed. This study was approved by the Ethics Committee of the Faculty of Human Kinetics (Technical University of Lisbon).

2.2. Video recording and analysis

Three high speed Basler A602fc cameras (Basler Vision Technologies, Ahrensburg, Germany) at 100 Hz were placed in position as to determine swing phases. A fourth Casio Ex-FH20 camera (Casio, Tokyo, Japan) at 1000 Hz was placed in front of the ball, in order to determine the instant of impact. Two reflective tapes (Horton et al., 2001) were placed on the club to divide the swing in three phases (Bechler et al., 1995; Pink et al., 1993; Watkins et al., 1996). (1) Backswing – from the beginning until the top of the swing; (2) Downswing – from the top until impact; and (3) Follow-Through – from impact until the end of the swing. SIMI 3D Motion system (SIMI Reality Motion System GmbH, Unterschleissheim, Germany) was used for EMG-synchronized 3D kinematic analysis.

2.3. EMG procedures

EMG data was collected with active surface electrodes (Al/AgCl, disk shape 10 mm of diameter) and bioPLUX® research 2010 telemetric equipment (Plux, Lisbon, Portugal). EMG data was collected with a 1000 Hz sampling frequency, amplified with a bandpass between 10 and 500 Hz, common-mode rejection ratio (CMRR) of 110 dB and input impedance greater than 100 MΩ. After stored, data was digitally filtered (10–490 Hz) and, full-wave rectified. Smoothing with a low pass filter (12 Hz, Butterworth 4th order digital filter) was applied and submitted to visual inspection comparison. EMG data processing was performed with MATLAB® V.R2010a software (Mathworks Inc., Natick Massachusetts, USA). Skin was properly prepared by means of hair removal, abrasion and alcohol cleaning. The electrodes were placed with a 20 mm center-to-center distance and applied in parallel to the muscle fibers: rectus abdominis (RA), 3 cm laterally from the umbilicus; external oblique (EO), 15 cm laterally from the umbilicus; erector spinae (ES), 3 cm laterally from the L3 spinous process (Horton et al., 2001). Muscle contraction was performed in order to visualize the muscle belly. The ground electrode was placed on the manubrium.

Three to four second-long maximum voluntary contractions (MVCs) were collected to determine baseline activity between two maximum voluntary contractions (MVCs): RA – in supine position, the participant performed trunk flexion at 30°, keeping the knees at 90° and the hip at 70°, with a researcher applying resistance on the shoulders, while another researcher bilaterally stabilized the lower limbs; EO – in lateral position, with hands on the chest and flexed legs (stabilized), the participant produced a lateral trunk flexion against the resistance presented by the researcher; ES – in prone position, with lower limbs stretched and pelvis fixated, the participant performed trunk extension against the bilateral shoulder resistance presented by the researcher (Konrad, 2005;

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