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THE SWALLOW ELEMENT AND MUSCULAR ACTIVATIONS

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Swallow is a strength hold element performed on rings routines by the world best gymnasts. The competitive value and the elements intrinsic difficulty are the main reasons to study it from the biomechanical point of view. The aim of this study was to characterize the swallow element in order to identify the muscular activation of the different muscles to create strategies of progression to learn this skill. Surface electromyography was used to evaluate 8 muscles during swallow performance in competitive contest. Results suggest that to perform the swallow element is necessary to stabilize the shoulder joint by activating infraspinatus, serratus anterior and trapezius inferior muscles, which will allow the anterior muscles to support the body mass in balance.

KEY WORDS: men's artistic gymnastics, rings, strength hold element, isometric contraction, surface electromyography.

INTRODUCTION: Men's Artistic Gymnastics (MAG) as a complex sport became much more risky in the last few years (Arkaev & Suchilin, 2004). MAG is today a sport with many different elements and combinations, where gymnasts attempt to execute the highest difficult elements, in order to increase as much as possible their routines value (Arkaev & Suchilin, 2004). According to Campos et al. (2009), the swallow element provides a competitive advantage when including in rings routines. Knowing that the value of each routine is determined by the 10 best elements performed upon the apparatus, swallow element has the advantage of being a high value element on rings with the possibility to be used twice in a routine (Fédération, 2009). Following this perspective our work arises to understand the swallow element performed in rings routines. Swallow is a strength hold element, held by hands support with the body and arms straight in a horizontal position at rings level – Figure 1 (Bernasconi & Tordi, 2005; Bernasconi et al., 2009; Sands et al., 2006). At competition field, every strength element must be held in a static position for 2 seconds, less than that and a deduction will be applied. If the gymnast doesn't hold for at least 1 second, the strength element will not be recognize for the routine value (Fédération, 2009). In a fifteen level's scale of progression on rings, the swallow comes up as the last strength element to be learned by the gymnasts (Cuk & Karácsony, 2002). In this way a deeper understanding of muscular coordination is required, in order to improve the swallow element technique and reduce the time preparing by focus on the main aspects of learning. Therefore using surface electromyography (EMG) we have evaluated the muscular behaviour of eight muscles - *biceps brachii, triceps brachii, serratus anterior, trapezius inferior, pectoralis major, latissimus dorsi, deltoid anterior and infraspinatus*; during the performance of swallow element. By measuring the muscular activation through EMG, we intend to understand the muscular coordination between those muscles. Combining the anatomical action of each evaluated muscle and their activation during swallow performance we intend to find the element ideals pattern of learning.

Figure 1: Swallow on rings.

METHODS: The experimental test was completed 1 month before European Artistic Gymnastics Championships 2009, by a male senior gymnast from the Portuguese National Team which was 6 times Word Cup finalist, and one time rings finalist at the European Championship. Our sample illustrates the Portuguese universe of gymnasts that are capable to perform swallow on rings. After a 15 minutes of general activation, was used a rubber band to mobilize the upper limb (UL), preparing the muscles and joints for the practical test. Following the code of point's requirements, only 2 seconds of contraction were analysed (Fédération, 2009). The swallow element was performed on rings as if in competition context during 4 seconds of isometric contraction. Only the last 2 seconds were used for analysis. Two trials were performed, with 5 minutes of rest between attempts (Bazett-Jones et al., 2005). Each trial was evaluated according to the code of point's demands by a Portuguese judge with national certification. Note that this work is part of a further investigation where the swallow element attempts would be compared to different training exercises using swallow position. The protocol started with skin preparation, shaving and cleaning the muscle belly with alcohol solution. Surface electrodes (Ag/AgCl Unilect) with circular shape (5mm of diameter and bipolar shape) were placed at muscle belly. Following SENIAM (1999) recommendations, the electrodes were placed at muscular belly, with 2cm of distance between their centre point with the same orientation of as muscle fibers. The earth electrode was placed at the olecranon bone. The surface EMG signal was recorded simultaneously from 8 different muscles from the right shoulder: *biceps brachii* (long head), *triceps brachii* (long head), *serratus anterior*, *trapezius inferior* (fibres with upper orientation), *pectoralis major*, *latissimus dorsi*, *deltoid anterior* (clavicular head) and *infraspinatus*. We used a pre-amplifier AD621 BN, with a gain of 100 and a common mode rejection ratio (CMRR) equal to 110 dB, to collect the EMG signal, and an analogical/digital (A/D) convertor of 16bits – BIOPAC System, Inc; with an input range of ±10 volts at acquisition rate of 1000 samples per second for 8 channels of EMG. The EMG signal was synchronised with the help of a video camera Sony® - GR-SX1 recording 50 frames per second and a led attached to the BIOPAC System, which lighted up during signal collection allowing to determining the exact start/ending moment of each attempt. The Acqknowledge® 3.2.5, BIOPAC System, was used for data acquisition, and MATLAB software for data evaluation, by removing DC offset, band pass filtering the signal from 10 to 350 Hz, signal rectification and signal conversion in root mean square (RMS) with a window of 250 milliseconds. An attempt of swallow element was performed until muscular exhaustion to collect the muscular signal of a maximal voluntary contraction (MVC) for data normalization and posterior calculation of muscular co-activation index (agonist/antagonist relation) by the following equation (Kellis et al., 2003):

$$\text{Co-activation index} = \frac{\text{RMS antagonist}}{\text{RMS agonist + RMS antagonist}} \times 100$$

The muscular co-activation index was calculated for the following muscles:

Table 1
Muscles distribution for muscular co-activation

	Agonist	Antagonist
1	*Biceps brachii (long head)*	*Triceps brachii (long head)*
2	*Serratus anterior*	*Trapezius inferior*
3	*Pectoralis major*	*Latissimus dorsi*
4	*Deltoid anterior*	*Infraspinatus*

For statistical analysis was used the Microsoft Office Excel 2007 software, being calculated the attempts mean using the RMS average of each muscle and the co-activation index among the attempts. To obtain the percentage of muscular activation was used the MVC recorded from each muscle as a 100% indicator.

RESULTS: As it is possible to see in Table 1, the highest muscular activation found belongs to *infraspinatus* muscle with 69,3% of MVC. Just a step below were found the muscles, *biceps brachii* with 60,9%, *triceps brachii* with 58,1% and *deltoid anterior* with 54,3% of MVC.

The muscles responsible for scapula mobilization, *serratus anterior* and *trapezius inferior* achieved the corresponding values of 53,3% and 45,1% of MVC. The muscle *pectoralis major* presented the lowest value of anterior muscles with 48,5% of MVC. On the other hand *latissimus dorsi* was by far the lowest activated muscle during the performance of swallow on rings, with 15% of MVC. The muscular co-activation indexes represented in Figure 3 are near 50% of co-activation for tree groups of agonist/antagonist muscles, *biceps*/*triceps*, *serratus*/*trapezius* and *deltoid*/*infraspinatus* muscles. Those similar co-contractions indicate that the agonist muscles had a slightly superior contractions comparing to the antagonist muscles in co-activation case of *biceps*/*triceps* and *serratus*/*trapezius*, and that *infraspinatus* as antagonist muscle was slightly more activated than *deltoid* as agonist. The lowest co-activation belongs to *pectoralis*/*latissimus dorsi*, indicating that *pectoralis* had superior levels of activation than *latissimus dorsi*.

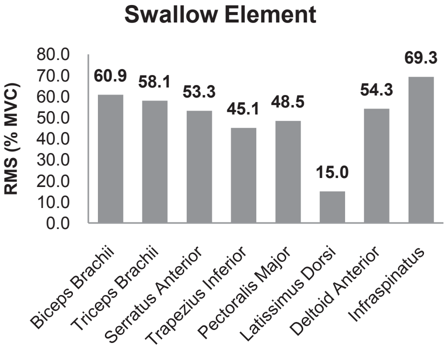

Figure 2: Percentage distribution of muscular activity (RMS) during swallow performance on rings.

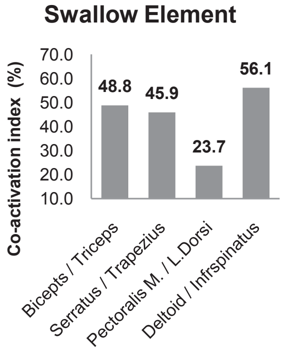

Figure 3: Co-activation index of agonist/antagonist muscles during swallow performance on rings.

DISCUSSION: Some studies show that swallow element performed on rings demands a large muscular coordination between shoulders muscles (Bernasconi & Tordi, 2005; Bernasconi et al., 2009; Sands et al., 2006). Being the shoulder's joint the most mobile joint of all body, Kapandji (2007), suggests that shoulder's muscles should act together to provide joint stability. The results in Figures 2 and 3 confirm that when muscles are able to produce a torque that equalized the external forces, the body balance necessary to perform swallow position is achieve (Gluck, 1982). The co-contractions near 50% of co-activation found between tree muscular groups – *biceps*/*triceps*, *serratus*/*trapezius* and *deltoid*/*infraspinatus* – seems to confirm the interaction between muscles to support the body on horizontal position. In the particular case of *serratus*/*trapezius* co-activation's, it seems that those muscles act to stabilize the scapula. Knowing that *trapezius inferior* acts as scapula depressor and stabilizer, while *serratus anterior* moves it forward and outward, co-opting it to thorax, the scapula stabilization of both muscles and the superior activation of *serratus anterior*, comparing to *trapezius*, seems to cause shoulder's protraction (Brukner & Khan, 1994; Kapandji, 2007; Kendall et al., 1993). Also the *infraspinatus* high activation - 69,3% of MVC, seems to confirm the importance of shoulder's stabilization for swallow performance on rings. The main action of this muscle is to prevent the humerus head forward dislocation, maintaining it on the glenoid cavity (Brukner & Khan, 1994; Kapandji, 2007; Kendall et al., 1993). The work of *infraspinatus*, *serratus anterior* and *trapezius inferior* seems to be determinant for scapula stabilization and consequently shoulder's stabilization, allowing the anterior muscles - *pectoralis major*, *biceps brachii*, *deltoid anterior*, to work as shoulder's flexors and support the body in the horizontal static position at rings level. Kapandji (2007), supports that *triceps brachii* push humerus head forward when the arm is extended at elbow joint. This means that the shoulder's protraction could be related with *serratus anterior* and *triceps brachii* muscular action, explaining also the higher activation of *infraspinatus*, which seems to act to prevent the excessive forward action. Working together, *pectoralis major*, *trapezius* and *latissimus dorsi* seem to act as scapula depressors {Kapandji, 2007 #77}. In the particular case of *latissimus dorsi*, as a muscle mainly responsible for UL adduction, during swallow execution it seems to work only as scapula depressor, explaining the lower activation shown by this muscle – 15% of MVC. This fact could also allow a slight abduction of UL, which is represented in the gymnast body external picture during swallow execution – Picture 1. Analyzing the specific muscular actions and transforming them into practical suggestions to improve training learning process, we are able to recommend the following external body position during swallow execution on rings:

Shoulder's joint protraction promoted by *trapezius inferior* and *serratus anterior* stabilizing and co-optioning the scapula, and also, by the action of *triceps brachii* moving humerus head forward;

UL depression promoted by *trapezius inferior*, *pectoralis major* and *latissimus dorsi* working as scapula depressors;

UL extended at elbow joint with external rotation, correspondingly promoted by *triceps brachii* and *infraspinatus* actions.

CONCLUSION: The swallow pattern of learning should begin with: shoulder's protraction, scapula depression and upper limb's external rotation with elbow joint extended. The first step of learning is to develop the muscular coordination in order to stabilize the scapula and the shoulder joint by a combined action of *serratus anterior*, *trapezius inferior* and *infraspinatus* muscles. With shoulders stabilized, it is possible to coordinate the muscular action of the anterior muscles in order to support the body mass in balance at rings level.

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