Portuguese Journal of Sport Sciences
11 (Suppl. 2), 2011

ELECTROMYOGRAPHIC ANALYSIS OF IMPINGEMENT SYNDROME: COMPARISON IN VOLLEYBALL ATHLETES

Leonor Oliveira, Camilo Moreira and Paulo Carvalho

School of Allied Health Sciences, Porto Polytechnic Institute, Porto, Portugal

The purpose of this study was to analyze the muscle activity of the trunk and shoulder complex during the volleyball serve and the possible correlation with the mechanisms of injury of impingement syndrome (IS). The athletes (female, n=15) were divided in three groups: 1) with pain, 2) without pain but with history of shoulder pain, and 3) without pain. Surface electromyographic data were collected from shoulder and trunk muscles and synchronized with video image recorded at high-speed. The data analysis revealed an increased activity in both Upper Trapezius and Infraespinatus and a decreased activity in Rectus Abdominus and External Oblique in the group with IS.

KEY WORDS: electromyography, impingement syndrome, serve, shoulder, stability, volleyball.

INTRODUCTION: Sports injuries are common and often recurrent and can result in cessation of the sport practice. Physical therapy has an increasingly important role not only in the treatment of these lesions but also at its prevention. So that the prevention and treatment programs can be adapted to the needs of each athlete and sport, a good understanding of the mechanisms of injury and its causes is required. Volleyball, being an overhead activity (Tilp et al., 2008; Borsa et al., 2008), has a great predisposition for overuse injuries at the shoulder, as the Impingement Syndrome (IS) (Verhagen et al., 2004; Ribeiro, 2007). Postural and anatomical alterations, soft tissue changes and neuromuscular disorders have been appointed as potential predispose factors for this pathology (Michener et al., 2003; Hanchard et al., 2004; Ludewig & Reynolds, 2009). Several studies (Magarey & Jones, 2003; Lugo et al., 2008) showed the importance of the periarticular muscles in shoulder stability and recently some researchers studied the relationship between trunk muscles activity and shoulder stability (Hodges & Richardson, 1997; Hodges et al., 1999; Moseley et al., 2002). Due to recent findings that indicate that muscle activity may be influenced by the presence of pain (Magarey & Jones, 2003; Ervilha et al., 2005), for this study there were created two groups for the athletes with IS: with and without pain.
The main purpose of this study was to analyze the activity of trunk and shoulder muscles during the volleyball serve and investigate its relationship to the injury mechanism of IS, by comparing groups of athletes with and without IS.

METHODS: Initially all athletes over 18 who regularly attended the weekly training sessions (> 3/weak) and weekly games (minimum 18/season) were included. All athletes that present: a history of severe trauma (fractures, dislocations), surgery on the shoulder, current treatment of the shoulder, positive symptoms in cervical evaluation and / or paresthesias (Ludewig & Cook, 2000), other diseases (Abate et al., 2009), regular physical activity (outside the team) were excluded. After the initial evaluation (questionnaire and physical assessment) 15 athletes were selected. The tests chosen for evaluation of the IS were the Hawkins-Kennedy Test and modified Neer Test. Both have high sensitivity values (92% and 75% respectively) but low specificity (22 to 44.3% and 33.5 to 47.5%, respectively). (Calis et al., 2000) Due to low specificity values only athletes that had both tests positive were included in the WP and WH groups. After the evaluation the athletes were divided into groups:
I. <u>Athletes without pain and without a history of IS</u> (WtP Group) - never had episodes of shoulder pain (> 1 week) and negative evaluation of the diagnostic tests for the IS.
II. <u>Athletes with pain</u> (WP Group) - feel pain at the moment. Physical examination positive for IS (both positive tests) and for the rotator cuff muscles (at least one positive).

III. Athletes without pain but with a history of IS (WH Group) – do not feel pain at the moment but report episodes of pain in the anterolateral aspect of the shoulder (> 1 week). Physical examination positive for IS (both positive tests) and for the rotator cuff muscles.
A surface EMG signal synchronized with the video system via activation of an LED was collected. A pressure transducer was fixed in the hand of the athlete to determine the moment of ball impact. With the video and transducer information it was possible to divide the serve into phases as described by Rokito and colleagues (Rokito et al., 1998).
Prior to the placement of the electrodes, the skin was carefully prepared through abrasion and cleaning to reduce impedance. The pairs of electrodes were placed with 20mm center distance and applied in parallel with the muscle fibers. The muscles studied were: Transversus/Internal Oblique (TrA), External Oblique (EO), Rectus Abdominus (RA) and Multifidus (Mult) for the trunk; and Infraspinatus (Infra), Upper Trapezius (UT), Lower Trapezius (LT), Serreatus Anterior (SA), Pectoral Major (PM) and Lastissimus Dorsi (LD) for the shoulder complex. The EMG signal was filtered with band-pass IRR to 25-450Hz followed by a high-pass FIR, Hamming 50Hz, with a coefficient of 800). It was then rectified, smoothed (window of 10 samples), integrated (Root Mean Square, 100 samples) and normalized to the maximum (obtained by manual muscular test) to allow quantifying the EMG signal in percentage of maximum activity. The data from each muscle was assessed by phase (cocking, acceleration, deceleration) and was then presented as mean values and standard deviation. For statistical analysis we combined the WP and WH group in a new group - With IS (WIS) and studied how it relates to the WtP using the nonparametric test Mann-Whitney, since the sample was not normally distributed and the groups were independent. We also looked for differences between WP and WH groups using the test previously described. The confidence interval used was 95% with a significance level of 0,05.
All participants were informed about the content of the study and its procedures by signing the informed consent form considering the "Helsinki Declaration" of the World Health Organization.

RESULTS: In the descriptive analysis of data we found some differences between WtP and WIS group. It is interesting to highlight the lower mean of activation of TrA/IO, EO and RA in the WIS group when compared to WtP. By contrast the mean values of Infra and UT muscles are increased in this group. The results are presented in Table 2. The muscles that reached statistically significant differences are marked in bold. We found a decreased activity of trunk muscles (OE and RA) and an increased activity of UT in the WIS group, with the exception of UT in acceleration phase. We also searched for differences between WH and WP group: in cocking there was a significant increase of EO, Infra, and SA activity in WtP group. In the acceleration phase the activity of TrA / IO and LD was significantly increased in WH group and the LT activity increased in WP group. Finally, during deceleration phase, TrA / IO and PM showed a significant increase in the WP group.

Table 1
Percentage of muscles activation in the different phases of movement for each group

		TrA	EO	RA	Mult	Infra	UT	LT	SA	PM	LD
Cocking	WtP	41 ± 28	**39 ± 15**	26 ± 18	10 ± 8	16 ± 4	**23 ± 9**	40 ± 22	35 ± 5	9 ± 3	8 ± 7
	WIS	22 ± 11	**25 ± 11**	17 ± 10	10 ± 6	23 ± 13	**37 ± 15**	27 ± 16	32 ± 15	10 ± 6	12 ± 9
Accel.	WtP	51 ± 15	**63 ± 23**	40 ± 22	35 ± 24	25 ± 11	21 ± 15	22 ± 11	65 ± 22	39 ± 21	20 ± 9
	WIS	40 ± 17	**40 ± 22**	33 ± 23	31 ± 25	36 ± 23	24 ± 24	21 ± 15	71 ± 20	56 ± 27	26 ± 18
Decel.	WtP	46 ± 20	28 ± 14	**20 ± 9**	42 ± 25	35 ± 20	**25 ± 9**	50 ± 13	53 ± 17	28 ± 20	29 ± 29
	WIS	28 ± 18	17 ± 11	**8 ± 6**	28 ± 18	37 ± 17	**38 ± 15**	53 ± 21	51 ± 26	30 ± 19	32 ± 21

WtP – without pain; WIS – with impingement syndrome; Value: Mean %MMA (percentage of maximum muscle activity) ± Standard Deviation.

DISCUSSION: In volleyball the serve is a repeated gesture which, due to its characteristics (fast movement, extremes of range of motion and high forces generated), is potentially harmful (Escamilla & Andrews, 2009) especially if the mechanisms of active stabilization are not effective. In fact, the imbalance of the stabilizers of the SC has been identified as a predisposing factor for IS (Michener et al., 2003; Hanchard et al., 2004; Ludewig & Reynolds, 2009), since its dysfunction causes a change of the axis of rotation and translation of the humeral head. (Magarey & Jones, 2003)

For this study it was decided to divide the movement into five phases in order to provide a more realistic and specific comparison of muscle activity since the EMG register is influenced by muscle length and the type and speed of contraction (Ludewig & Cook, 2000; Correia & Mil-Homens, 2004). We only analized the phases of cocking, acceleration and deceleration because these have greater mechanical and muscle stress (Escamilla & Andrews, 2009) and no significant difference was found in the execution speed of the gesture. On a statistical level, significant differences were found between the WtP and WIS groups at the level of activation of EO, RA and UT. No studies were found that correlate trunk muscles activity and shoulder pathologies so we cannot support this conclusion with bibliography apart from the one which describes the existence of a pre-activation of these muscles during movements of the upper limb (Hodges & Richardson, 1997; Hodges et al., 1999). However, in other areas of Physiotherapy, trunk stabilizers are seen as a support base that enables the efficient activity of the SC (Champion et al., 2009). Therefore it would seem that a decrease in postural stability would influence the stability of SC, which could be an explanation for these results. Moreover, the increased activity of the UT in the WIS group is congruent with what has been described in other studies (Ludewig & Cook, 2000; Cools et al., 2007), resulting in an imbalance of forces at the level of ST joint and thus altering the scapulohumeral rhythm.

Contrary to what had been initially hypothesized, Infra activity was increased in WIS group. One possible explanation for this result is that the maximum manual test would be painful for athletes from this group, the maximum value being underestimated. In fact, when comparing the mean value of the maximum force obtained in the manual test for this muscle, the WP is the group that has the lower value (WP- 0,29; WH- 0,41; WtP- 0,33).

Although it did not reach significant statistic values, the TrA / IO in the descriptive analysis showed a mean activity over 15% higher in the WtP at all phases of the movement. This tendency was followed by the other trunk muscles (EO and RA). These data, combined with what was previously mentioned, can lead to consider a relationship between postural stability and IS that should be studied and better understood in future studies.

When compared the WP and WH group there were significant differences in terms of TrA / IO, EO, SA, Infra, LT, PM and LD. Unlike hypothesized, SC stabilizers (Infra, SA and LT) are increased in the WP group. One possible explanation for these results is that the subjects are competitive athletes that maintain sport activity even during pain episodes, which may have led to the acquisition of compensative motor strategies.

This study has limitations such as the small size and type of sample selection, making it difficult to generalize the results to other groups not represented in the sample, therefore limiting the external validity. Some common limitations to EMG were aggravated due to the requirement of motion and its speed. It should be considered the possible movement of the muscle belly in relation to the electrode surface and possible contamination of other muscles activity (cross-talking) due to the high amplitude and direction of motion. The movement itself, although presented here as it is in the literature, varies among athletes. By analyzing the data in different phases we tried to minimize these differences but we cannot assure that the study was not influenced. The fact that we have considered a general classification (IS) and non-specific dysfunctions may have resulted in the inclusion of athletes with different disorders in the same group which may have rendered the results less clear.

Future research is needed to confirm the findings of this study and clarify whether there is relationship between postural stability and the IS. Other variables should be considered as the motor control is not only based on the amount of muscle activation but also on the sequence and timing of activation.

CONCLUSION: Our data indicates that the athletes with IS show levels of muscle activity, in terms of trunk and SC stabilizers, significantly lower than athletes without IS. Allowing us to support that there is a relationship between the level of activity of the stabilizers and the IS.

REFERENCES:

Abate, M., Silbernage, K., Siljeholm, K, Di Iorio, A., De Amicis, D.& Paganelli, R. (2009). Pathogenesis of tendinopathies: inflammation or degeneration? *Arthritis Research & Therapy,* 11, 235-250.

Borsa, P., Laudner, K. & Saue, E. (2008). Mobility and Stability Adaptations in the Shoulder of the Overhead Athlete. *Sports Med*, 38, 17-36.

Calis, M., Akgun, K., Birtane, M., Karacan, I., Calis, H. & Tuzun, F. (2000). Diagnostic values of clinical diagnostic tests in subacromial impingement syndrome. *Annals of Rheumatic Disease*, 59, 44-47.

Champion, B. & Lynch-Ellerington, M. (2009) Recovery of Upper Limb Function. In: Raine, S., Meadows, L. & Lynch-Ellerington, M. *Bobath Concept - Theory and Clinical Practice in Neurological Rehabilitation* (pp154-181). United Kingdom: Wiley-Blackwell.

Cools, A.M., Declercq, G.A., Cambier, D.C., Mahieu, N.N. & Witvrouw, E.E. (2007). Trapezius activity and intramuscular balance during isokinetic exercise in overhead athletes with impingement symptoms. *Scandinavian Journal of Medicine & Science in Sports,* 17, 25-33.

Ervilha, U., Farina, D., Arendt-Nielsen, L. & Graven-Nielsen T. (2005). Experimental muscle pain changes motor control strategies in dynamic contractions*. Exp Brain Res,* 164, 1432-1106.

Escamilla, R. & Andrews, J. (2009) Shoulder Muscle Recruitment Patterns and Related Biomechanics during Upper Extremity Sports. *Sports Med*, 39, 569-590.

Hanchard, N., Cummins, J. & Jeffries, C. (2004). Evidence-based clinical guidelines for the diagnosis, assessement and physicaltherapy management of shoulder impingement syndrome. *Chartered Society of Physiotherapy, London.*

Hess, S.A. (2000). Functional stability of the glenohumeral joint. *Manual Therapy,* 5, 63-71.

Hodges, P., Cresswell, A. & Thorstensson, A. (1999). Preparatory trunk motion accompanies rapid upper limb movement. *Exp Brain Res,* 124, 69-79.

Hodges, P.W. & Richardson, C.A. (1997). Contraction of the Abdominal Muscles Associated with Movement of the Lower Limb. *Physical Therapy,* 77, 142-4.

Ludewig, P.M. & Cook, T.M. (2000). Alterations in Shoulder Kinematics and Associated Muscle Activity in People With Symptoms of Shoulder Impingement. *Physical Therapy,* 80, 276-91.

Ludewig, P.M. & Reynolds, J.F. (2009). The Association of Scapular Kinematics and Glenohumeral Joint Pathologies. *J Orthop Sports Phys Ther,* 39, 90-104.

Lugo, R., Kung, P. & Ma, C. (2008). Shoulder biomechanics. *Eur Journal of Radiology,* 68, 16-24.

Magarey, M.E. & Jones, M.A. (2003). Dynamic evaluation and early management of altered motor control around the shoulder complex. *Manual Therapy,* 8, 195–206.

Michener, L.A., McClure, P.W. & Karduna, A.R. (2003). Anatomical and biomechanical mechanisms of subacromial impingement syndrome. *Clinical Biomechanics,* 18, 369–379.

Moseley, G.L., Hodges, P.W. & Gandevia, S.G. (2002). Deep and superficial fibers of the lumbar multifidus muscle are differentially active during voluntary arm movements. *Spine,* 27, E29-36.

Pezarat-Correia, P. & Mil-Homens, P. (2004). *A Electromiografia no Estudo do Movimento Humano.* Cruz Quebrada: FMH Edições.

Ribeiro, F. (2007). Incidência de Lesões no Voleibol: Acompanhamento de uma Época Desportiva. *Arquivos de Fisioterapia*, 1, 29-34.

Rokito, A., Jobe, F., Pink, M., Perry, J. & Brault, J. (1998). Electromyographic analysis of shoulder function during the volleyball serve and spike. *Journal of Shoulder and Elbow Surgery,* 7, 256-63.

Tilp, M., Wagner, H. & Müller, H. (2008). Differences in 3D kinematics between volleyball and beach volleyball spike movements*. Sports Biomechanics,* 7, 386–397.

Verhagen, E., Beek, A., Bouter, L. & Bahr, R. (2004). A one season prospective cohort study of volleyball injuries. *Br J Sports Med,* 38, 477–481.