DOES SHOULDER IMPINGEMENT SYNDROME AFFECT THE SHOULDER KINEMATICS AND ASSOCIATED MUSCLE ACTIVITY IN ARCHERS?

H. Shinohara[1,2], Y. Urabe[1], N. Maeda[1], D. Xie[1], J. Sasadai[1], E. Fujii[1]

1. Graduate School of Biomedical and Health Sciences, Hiroshima University, Kasumi 1-2-3, Minami-ku, Hiroshima 734-8553, Japan
2. Southern Clinic Orthopedics and Internal Medicine, Ebahonmachi 5-28, Naka-ku, Hiroshima 730-0833, Japan

Short title: Does impingement affect archery shooting form?

Acknowledgements

The authors express their appreciation to Mr. Atsuhiro Toda and Mr. Shinji Kanegawa for their contribution to the recruitment of subjects.

Corresponding author

Hiroshi Shinohara

TEL: +81 82-257-6337

FAX: +81 82-257-5344

E-mail: hiroshinohara@rock.odn.ne.jp

Abstract

Aim: Archery related injuries, such as shoulder impingement syndrome are caused by repeated motion of the shoulder. The aim of this study is to analyze differences in the shoulder kinematics and the associated muscle activity between archers with shoulder impingement and uninjured archery players.

Methods: Thirty male archers, who were divided into an impingement group and an uninjured group, were included in this study. The angle of scapular elevation, shoulder joint abduction, horizontal extension, and elbow joint flexion as well as the electromyographic activity of the upper trapezius, lower trapezius, deltoid middle, deltoid posterior, biceps brachii, and triceps brachii muscles at the point of stabilization during shooting were measured. Variables differing between impingement and uninjured groups were identified, and a stepwise regression analysis was performed to identify a combination of variables that effectively impingement syndrome.

Results: The impingement group had a greater angle of scapular elevation, smaller angle of horizontal extension, smaller angle of elbow flexion, higher the levels of upper trapezius, lower the levels of lower trapezius, higher deltoid middle muscle activity and higher UT/LT ratio (all differences were significant). A logistic model for predicting impingement syndrome showed that UT/LT ratio was significantly related impingement syndrome ($p < 0.05$).

Conclusion: The authors concluded that archers with shoulder impingement syndrome exhibit different kinematics and muscle activity compared to uninjured archers. Therefore, in order to prevent shoulder joint impingement during archery, training is necessary what can make lower trapezius muscle activity increased to decrease the UT/LT ratio.

Keywords: archery, kinematics, electromyography, shoulder impingement syndrome

Introduction

Archery requires the ability to shoot an arrow at a given target with accuracy. The rules of the International Archery Federation allow for the following shooting distances: 90 m, 70 m, 50 m, and 30 m for men; 70 m, 60 m, 50 m, and 30 m for women. The large number of shots (144) undertaken in 1 day by competitors requires a very reliable action. The shot in archery is commonly described as consisting of 3 phases: 1) the stance, 2) the arming phase, during which the archer pushes the bow and pulls the bow string, and 3) the sighting phase, which involves the final stretching of the bow while targeting. [1] The arming phase consists of dynamic work of the shoulder joint and the sighting phase almost isometrically loads the shoulder girdle. [2] During the sighting phase, the shoulder joint maintains internal rotation, flexion, and horizontal extension for a few seconds.

The bow strength of the full draw position is said to be around 42 pounds in men. Repetition of target practice movements causes shoulder pain. Therefore, right shoulder pain in archery players was reported to be an occupational hazard. [3] Mann and Littke confirmed pain of the glenohumeral joint on the draw side in 6 out of 21 archers, while 7 archers showed a positive sign upon the impingement test. [4] The most frequently reported cause of shoulder pain in overhead sports athletes is impingement syndrome. [5] Previous studies have reported that the archery player often suffers acute injury to the forearm and finger; [6, 7] however, shoulder impingement syndrome is also a serious problem.

The shoulder impingement syndrome change sports performance and the activity of the shoulder girdle and upper extremity muscles. Scapula elevation during shoulder joint abduction is increased in baseball players with shoulder impingement. [8] In addition, swimmers with a history of shoulder pain have high upper trapezius muscle fiber activity levels, as a result of abduction of the humerus during swimming. [9] Previous studies have also reported that individuals with shoulder impingement exhibit lower levels of lower trapezius muscle activity. [10, 11] The deltoid muscle plays an important role in the pathomechanics of impingement, due to its ability to offer upwardly directed force.[12] Another reports suggested that the humerus is moved through horizontal extension towards full drawing the bow, the supraspinatus and long head of biceps brachii are rubbed along the coracoacromial arch.[4] Therefore, the shoulder impingement syndrome may change archery shooting form and the activity of the shoulder girdle and upper extremity muscles similarly. However, to date, there are no reports comparing kinematic and electromyographic findings in archers with and without shoulder impingement. The clarification of the differences in shooting form between shoulder impingement syndrome and uninjured archers is necessary to assist prevention of a shoulder pain and the dysfunction. And it is necessary to investigate what kind of item is a factor to affect most.

The aim of this study is to identify risk factors for impingement syndrome in archers. The kinematics and the shoulder girdle, upper extremity muscle activity were assessed in archers classified as either uninjured or impingement syndrome. The present study hypothesized that archers with impingement syndrome would exhibit a large scapular elevation angle and a higher levels of upper trapezius and deltoid muscle activity than those without this syndrome.

Materials and methods

Participants

Thirty male high-school collegiate archers participated in this study. A completed and signed informed consent form was obtained from each participant before the study. The study protocol was approved by the Ethics Committee of the Graduate School of Health Sciences, Hiroshima University (ID number, 1172).

All subjects completed questionnaires about their history of shoulder pain and training. Information on participants, including years of archery experience and age, is presented in

Table 1. All the participants were right-handed and used their right hand for the drawing movement during archery.

Subjects were excluded if they had a history of dislocation of the shoulder, shoulder surgery, current symptoms related to the cervical spine, or documented structural injuries to the shoulder complex. Participants who reported any pain and/or discomfort in the upper extremity during the experiment were also excluded from this study.

The subjects were classified into 2 groups, a shoulder impingement group (n = 8) and an uninjured shoulder group (n = 22). Subjects were included in the impingement group if they had at least 2 of the following 5 criteria in addition to a history of shoulder pain: [9, 13, 14] (1) a positive Neer sign, reproduction of pain when the examiner passively flexed the humerus to the end-range with overpressure; (2) a positive Hawkins sign, reproduction of pain when the shoulder was passively placed in 90° forward flexion and internally rotated to the end-range; (3) a positive Jobe's sign, reproduction of pain and lack of force production with isometric elevation in the scapular plane during internal rotation (empty can); (4) pain with apprehension, reproduction of pain when an anteriorly directed force was applied to the proximal humerus in the position of 90° abduction and 90° external rotation; and (5) positive relocation, reduction of pain after a positive apprehension test when a posteriorly directed force was applied to the proximal humerus in the position of 90°/90°.

Motion analysis

Arrow shooting data were collected in an indoor biomechanics laboratory (Fig. 1). After regular warm-up, each participant shot 5 arrows towards a target placed at a 2-m distance. A mark of 1-cm in diameter was stuck on the target, and the archers aimed at this mark each time.

Shooting motion data were obtained using 5 high-speed cameras (FKN-HC200C;

4assist, Japan); the 5 video images were electronically synchronized at 200 frames per second. The cameras were placed such that reflective markers attached to the archers would be caught by at least 2 cameras in the full drawing phase (Fig. 1). The full drawing position, defined as the moment when a clicker (a bow item) fell, was selected for further data analysis.

Four reflective markers (10-mm diameter) were placed over the right radial styloid process, lateral epicondyle, acromion, and spinous processes of the 7th cervical vertebra (C7). Right scapular elevation, shoulder abduction, shoulder horizontal extension angle, and elbow flexion angle were then computed for the full drawing position. The scapular elevation angle was defined as the angle between the line formed between the C7 and acromion markers and the perpendicular line in the frontal plane. The shoulder abduction angle was measured as the angle between the line formed between the acromion and lateral epicondyle and the perpendicular line, according to Green's method. [15] The shoulder horizontal extension angle was defined as the angle between the lines formed between the C7 and acromion markers and between the acromion and lateral epicondyle markers, in the horizontal plane. The elbow flexion angle was defined as the angle between the lines formed between the acromion and lateral epicondyle markers and between the lateral epicondyle and radial styloid process markers, in the horizontal plane.

The video images were superimposed onto a computer display and the markers were automatically tracked using a 2- to 3-dimensional motion analyzer (DippMotion XD; Ditect, Tokyo, Japan). The authors then obtained digitized points by using a direct linear transformation method. [16] These motion analysis data demonstrated good trial-to-trial reliability (intraclass correlation coefficients > 0.97).

Electromyographic (EMG) analysis

Prior to electrode application, the skin was cleaned by scrubbing with alcohol to reduce skin impedance. Ag/AgCl electrodes (Blue Sensor; Medicotest, Olstykke, Denmark) with a center-to-center distance of 2 cm were placed longitudinally on the muscle belly along the upper trapezius, lower trapezius, deltoid middle, deltoid posterior, biceps brachii, and triceps brachii muscles. [17] The reference electrode was placed on the olecranon process of the ulna. Electromyography (EMG) data were amplified (Bio-amp ML132; AD Instruments, Oisaka, Hiroshima, Japan), underwent analog/digital (A/D) conversion at 1 kHz, and were rectified (Mac Lab/8s; AD Instruments, Oisaka, Hiroshima, Japan) with a high-pass filter at 500 Hz and a low-pass filter at 20 Hz.

EMG activities of the upper trapezius, lower trapezius, deltoid middle, deltoid posterior, biceps brachii, and triceps brachii were quantified. EMG data from the 5 shots taken were full-wave rectified. The data were then analyzed using an integral calculus level of 1 second from the fall of the clicker. Prior to the shots, the maximum voluntary contractions (MVC) of the upper trapezius, lower trapezius, deltoid middle, deltoid posterior, biceps brachii, and triceps brachii of each archer were determined.

Isolated maximum muscle contraction was measured by manual muscle testing. [18, 19] Subjects performed 3-second maximum voluntary isometric muscle contractions against manual resistance. The isometric contraction of the upper trapezius was tested in the sitting position. Resistance was applied to elevation of the scapula. Lower trapezius strength was tested in the prone position with the shoulder angle at 140° flexion and 135° abduction. Resistance was placed in the middle line of the scapula, between the acromion and the spine of the scapula. The deltoid middle was tested in the sitting position with the shoulder angle at 90° abduction; resistance was again applied to abduction of the humerus. The deltoid posterior was tested in the prone position with the shoulder angle at 90° abduction, with resistance applied to horizontal extension of the humerus. The biceps brachii was tested in the sitting position with the shoulder angle at 0° flexion and 90° elbow flexion; here, resistance was applied to flexion of the elbow joint. The triceps brachii was tested in the prone position with the shoulder angle at 0° flexion, 90° abduction, and 90° elbow flexion; resistance was applied to flexion of the elbow joint. The mean value was adopted after the MVC were measured 3 times. After full-wave rectifying, EMG amplitudes were normalized with respect to MVC. %MVC was calculated for each muscle and for each archer. In this way, relative EMG signal values were obtained on the basis of muscle strength. These EMG data demonstrated good trial-to-trial reliability (intraclass correlation coefficients > 0.82). The EMG signals and kinematics data were synchronized using a digital timing signal counter (custom made) and recorded using the software in the high-speed cameras.

Statistical analysis

Data are expressed as mean ± SD. The uninjured and impingement groups were compared to detect mean differences between the two groups for continuous variables using unpaired t-test. The variables that achieved statistical significance were then included in a multivariate logistic regression analysis. The entry probability for logistic regression analysis was set at the 0.10 level of significance rather than the 0.05 level, because of the sample size and number of variables, in an attempt to avoid type 2 errors. The model was simplified in a stepwise fashion by removing variables with a P-value > 0.05. Odds ratios (OR) and 95% confidence intervals (CI) were calculated for the impingement syndrome associated with independent variables. The Hosmer-Lemeshow goodness-of-fit statistic was used to assess if the model fit the data.

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS Inc., Chicago, IL, USA) ver. 20.0J for Windows®. A p-value of < 0.05 was considered to be statistically significant with the exception of the entry probability for logistic analysis mentioned above.

Results

Age, height, body weight, BMI, bow weight, and years of training were not significantly different between the impingement and the uninjured groups (Table 1).

The kinematic data of the impingement and uninjured groups are presented in Table 1. The average value of the scapular elevation angle was 92.9 ± 8.7° in the impingement group and 85.7 ± 6.0° in the uninjured group; thus, the impingement group showed a significantly higher scapular elevation angle compared to the uninjured group ($p < 0.05$). In contrast, the impingement group demonstrated a significantly smaller horizontal extension angle (135.8 ± 16.1°) compared to the uninjured group (152.2 ± 8.3°) ($p < 0.05$). The average value of the elbow flexion angle was 138.9 ± 4.9° in the impingement group; this was significantly smaller than the angle of 143.3 ± 5.1° in the uninjured group ($p < 0.05$).

The shoulder girdle and upper extremity muscle activities of the impingement and uninjured groups are also shown in Table 1. The muscle activity of the upper trapezius was significantly higher in the impingement group than in the uninjured group ($p < 0.05$), while the muscle activity of the lower trapezius was significantly lower in the impingement group than in the uninjured group ($p < 0.05$). The average ratio of the activity of the upper trapezius to that of the lower trapezius was 2.15 ± 0.47 in the impingement group and 1.32 ± 0.28 in the uninjured group; this ratio was significantly larger in the impingement group ($p < 0.01$). The muscle activity of the deltoid middle was significantly higher in the impingement group than in the uninjured group ($p < 0.05$), while there were no significant differences in the muscle activities of the deltoid posterior, biceps brachii, and triceps brachii between the 2 groups.

The Hosmer-Lmeshow statistic was $\chi^2 = 11.95$, adopting the null hypothesis. UT/LT ratio was subjected to logistic regression analysis using the occurrence of impingement syndrome as a dependent variable. Based on the caluculated OR, UT/LT ratio was found to be significantly related to shoulder impingement syndrome ($p = 0.014$, Table 2).

Discussion

In this study, the authors examined archery kinematics, including the angles of the scapula, shoulder, elbows, and shoulder girdle as well as upper extremity muscle activity during the sighting phase. In line with the hypothesis of this study, kinematics between archers with impingement syndrome and normal archers were different. Greater scapula elevation and smaller shoulder horizontal extension and elbow flexion were observed during shooting movements in archers with impingement syndrome. The internal factor of increase UT/LT ratio is, in particular, a risk factor closely associated with shoulder impingement syndrome. Change in the shooting form of archers with impingement syndrome is a new and extremely interesting finding.

The authors examined shoulder joint abduction movements and found that there was a significant difference between the 2 archery groups in terms of the scapula elevation angle. Previous studies have observed the scapula in an elevated position during shoulder abduction in impingement syndrome. [20-22] Previous studies have also reported that individuals with shoulder impingement exhibit higher levels of upper trapezius muscle activity and lower levels of lower trapezius muscle activity. [10, 11] Altered muscle activity in shoulders with impingement signs suggests muscle dysfunction in the trapezius muscle related to shoulder pathology. [23] The archer with impingement syndrome was shown to become scapula movement and the muscle activity of trapezius similar to overhead sports in the impingement group. Therefore, in order to find archers with shoulder impingement, assessment of scapula position and trapezius muscle activity during archery may be necessary.

Horizontal extension of the shoulder joint angle was lower in the impingement group when compared to the uninjured group. The deltoid posterior plays a significant role in horizontal extension. However, there were no significant differences in the muscle activity of the deltoid posterior in the present study. Therefore, a significant difference in shoulder horizontal extension angle may be explained by the strength of the deltoid posterior. Interestingly, the muscle activity of the deltoid posterior was about 100% MVC in both groups. Another reports also showed that the deltoid posterior plays a significant role in drawing during archery. [1, 2] This value slightly differ from the previous study, in which the muscle activity of the deltoid posterior was about 40–50% MVC during shooting. [1] It is possible that the muscle activity of the deltoid posterior was different in the current study when compared to this previous report, because MVC in the previous study was measured using an ergometer. Therefore the authors think that the deltoid posterior is one of most necessary factors for archery.

The elbow flexion angle was smaller in the impingement group when compared to the uninjured group. There were no significant differences in the muscle activities of the biceps brachii and triceps brachii. The difference of elbow flexion angle might be due to a difference of horizontal extension angle in particular. The sighting phase was the posture by which archers put their pulled hands onto their mandible. Because a position of the hand is in a fixed state, the authors think that elbow joint flexion angles increase by a chain reaction if shoulder horizontal extension is high or wrist dorsiflexion is high. This mechanism explains the reason that activities of the biceps brachii muscle did not become high in the uninjured group.

The results of this study showed that the impingement group exhibited a higher level of deltoid middle and upper trapezius muscle activity and a lower level of lower trapezius muscle activity. The deltoid plays an important role in the pathomechanics of impingement, due to its ability to offer upwardly directed force. [12] Moreover, the combination of shoulder joint internal rotation and flexion narrows the space under the coracoacromial arch. [24, 25]

Shoulder impingement syndrome may be caused by increased activation of the deltoid middle muscle, narrowing of the space under the coracoacromial arch by the upper trapezius, and a combination of internal rotation with shoulder joint flexion. In addition, archers keep the posture of shoulder joint flexion and internal rotation a few seconds usually. This mechanism of causing impingement may be particular to archery.

By applying a logistic regression analysis on the occurrence of the shoulder impingement syndrome as a dependent variable, the OR of UT/LT was significant, and there was selected as a factor contributing to impingement syndrome in the present study. The UT/LT ratio was 2.15 and 1.32 in the impingement and the uninjured groups, respectively. One report showed that the UT/LT was 2.19 in the impingement group and 1.23 in the uninjured group; the UT/LT ratio in the impingement group was significantly greater than that in the uninjured group during isokinetic shoulder joint abduction movements. [23] The results of the current study were similar. These values slightly differ from the previous study, in which UT generates 52% and LT 68% of MVC during abduction in the frontal plane. [26] However, in that study, the movement was performed with a dumbbell in a submaximal exercise, whereas our protocol required the muscle of deltoid maximal effort during the archery shooting motion. Therefore, in order to prevent shoulder joint impingement during archery, training of the lower trapezius muscle is necessary to decrease the UT/LT ratio.

This study had several limitations. First, the subjects were men. Shoulder joint disorders have been reported to be more common in female archers. [4] Therefore, collecting data on female archers and comparison of this data with findings in male archers is a necessary future study. Second, the levels of rotator cuff and serratus anterior muscle activity were not measured in this study. The rotator cuff and the serratus anterior are considered to be important muscle groups acting to prevent impingement. [11, 27] However, the authors considered that the measurement of the triceps brachii, biceps brachii, and so on was necessary, besides the muscles around the scapula. In the future, the authors consider investigation of movement of the scapula and muscle activity around the scapula important. It may be possible to better analyze archery shoulder pain prevention measures by measuring the level of rotator cuff and serratus anterior muscle activity in a future study. Finally, only the elevation of the scapula could be measured in this study. Upward rotation, external rotation, and posterior tilt of the scapula are also believed to be important movements for expanding the subacromial space. [28, 29] It is possible that the angles of upward rotation, external rotation, and posterior tilt of the scapula were all low in the impingement group; therefore, further detailed investigation of scapular movement is required.

Many previous archery-related studies have attempted to correlate the level of forearm muscle activity with differences in competitive abilities. [30, 31] The authors of the current study firstly examined the relationship between shoulder girdle upper extremity muscle activity during the shooting motion and shoulder injury in archers. A greater scapula elevation angle and a lower shoulder horizontal extension angle during archery shooting form were observed in the impingement group in this study. These results were considered to show that muscle activation is related. These finding are important for preventing and alleviating shoulder pain for archers. In the future, the authors wish to examine whether the change in the angle of scapular elevation during the shooting motion in archers with impingement results in an increased activity level in the lower trapezius muscle, and thus reduces the occurrence of impingement.

Conclusion

This study compared the joint angles of the upper limbs and shoulder girdle upper extremity muscle activity levels in 2 groups of archers, with and without shoulder impingement syndrome. Lower shoulder joint horizontal extension angle, a higher level of upper trapezius muscle activity, a lower level of lower trapezius muscle activity, and a higher level of deltoid middle muscle activity were observed in the impingement group. Improvement of lower trapezius muscle activity level to decrease the UT/LT ratio when performing static shoulder joint movements in archery may decrease the severity of impingement syndrome.

References

1. Leroyer P, Van Hoecke J, Helal JN. Biomechanical study of the final push-pull in archery. J Sports Sci 1993;11:63-9.
2. Hennessy MP, Parker AW. Electromyography of arrow release in archery. Electromyogr Clin Neurophysiol 1990;30:7-17.
3. Fukuda H, Neer CS, 2nd. Archer's shoulder. Recurrent posterior subluxation and dislocation of the shoulder in two archers. Orthopedics 1988;11:171-4.
4. Mann DL, Littke N. Shoulder injuries in archery. Can J Sport Sci 1989;14:85-92.
5. Neer CS, 2nd. Impingement lesions. Clin Orthop Relat Res 1983:70-7.
6. Rayan GM. Archery-related injuries of the hand, forearm, and elbow. South Med J 1992;85:961-4.
7. Palsbo SE. Epidemiology of recreational archery injuries: implications for archery ranges and injury prevention. J Sports Med Phys Fitness 2012;52:293-9.
8. Lin JJ, Hsieh SC, Cheng WC, Chen WC, Lai Y. Adaptive patterns of movement during arm elevation test in patients with shoulder impingement syndrome. J Orthop Res 2011;29:653-7.
9. Ruwe PA, Pink M, Jobe FW, Perry J, Scovazzo ML. The normal and the painful shoulders during the breaststroke. Electromyographic and cinematographic analysis of twelve muscles. Am J Sports Med 1994;22:789-96.
10. Wadsworth DJ, Bullock-Saxton JE. Recruitment patterns of the scapular rotator muscles in freestyle swimmers with subacromial impingement. Int J Sports Med 1997;18:618-24.
11. Cools AM, Witvrouw EE, De Clercq GA, Danneels LA, Willems TM, Cambier DC, et al. Scapular muscle recruitment pattern: electromyographic response of the trapezius muscle to sudden shoulder movement before and after a fatiguing exercise. J Orthop Sports Phys Ther 2002;32:221-9.
12. Reddy AS, Mohr KJ, Pink MM, Jobe FW. Electromyographic analysis of the deltoid and rotator cuff muscles in persons with subacromial impingement. J Shoulder Elbow Surg 2000;9:519-23.
13. Cools AM, Witvrouw EE, Mahieu NN, Danneels LA. Isokinetic Scapular Muscle Performance in Overhead Athletes With and Without Impingement Symptoms. J Athl Train 2005;40:104-10.
14. Speer KP, Hannafin JA, Altchek DW, Warren RF. An evaluation of the shoulder relocation test. Am J Sports Med 1994;22:177-83.
15. Green RA, Taylor NF, Watson L, Ardern C. Altered scapula position in elite young cricketers with shoulder problems. J Sci Med Sport 2012.

16. Abdel-Aziz YI, Karara HM. Direct linear transformation from comparator coordinates in close-range photogrammetry. In: Proceedings American Society of Photogrammetry Symposium on Close-Range Photogrammetry. Falls Church, VA: American Society of Photogrammetry Symposium on Close-Range Photogrammetry. 1971. p.1–19.

17. Perotto A, Delagi E, Iazzetti J, Morrison D. Anatomic Guide to Electromyography: The Limbs and the Trunk. Third edition. Springfield: Charles C. Thomas;1994.

18. Kendall F, Kendall E. Muscles, Testing and Function. Baltimore: Williams and Wilkins;1983.

19. Celik D, Sirmen B, Demirhan M. The relationship of muscle strength and pain in subacromial impingement syndrome. Acta Orthop Traumatol Turc 2011;45:79-84.

20. Laudner KG, Myers JB, Pasquale MR, Bradley JP, Lephart SM. Scapular dysfunction in throwers with pathologic internal impingement. J Orthop Sports Phys Ther 2006;36:485-94.

21. Lin JJ, Hanten WP, Olson SL, Roddey TS, Soto-quijano DA, Lim HK, et al. Functional activity characteristics of individuals with shoulder dysfunctions. J Electromyogr Kinesiol 2005;15:576-86.

22. Lukasiewicz AC, McClure P, Michener L, Pratt N, Sennett B. Comparison of 3-dimensional scapular position and orientation between subjects with and without shoulder impingement. J Orthop Sports Phys Ther 1999;29:574-83; discussion 84-6.

23. Cools AM, Declercq GA, Cambier DC, Mahieu NN, Witvrouw EE. Trapezius activity and intramuscular balance during isokinetic exercise in overhead athletes with impingement symptoms. Scand J Med Sci Sports 2007;17:25-33.

24. Graichen H, Bonel H, Stammberger T, Englmeier KH, Reiser M, Eckstein F. Subacromial space width changes during abduction and rotation--a 3-D MR imaging study. Surg Radiol Anat 1999;21:59-64.

25. Hawkins RJ, Hobeika PE. Impingement syndrome in the athletic shoulder. Clin Sports Med 1983;2:391-405.

26. Moseley JB Jr., Jobe FW, Pink M, Perry J, Tibone J. EMG analysis of the scapular muscles during a shoulder rehabilitation program. Am J Sports Med 1992;20:128-34.

27. Pappas AM, Zawacki RM, McCarthy CF. Rehabilitation of the pitching shoulder. Am J Sports Med 1985;13:223-35.

28. Graichen H, Bonel H, Stammberger T, Haubner M, Rohrer H, Englmeier KH, et al. Three-dimensional analysis of the width of the subacromial space in healthy subjects and patients with impingement syndrome. AJR Am J Roentgenol 1999;172:1081-6.

29. Ludewig PM, Cook TM. Alterations in shoulder kinematics and associated muscle activity in people with symptoms of shoulder impingement. Phys Ther 2000;80:276-91.

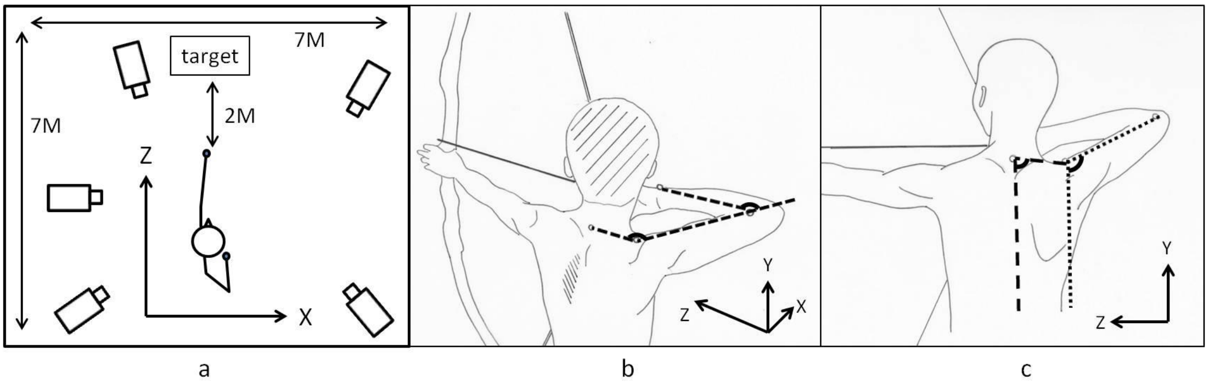
30. Clarys JP, Cabri J, Bollens E, Sleeckx R, Taeymans J, Vermeiren M, et al. Muscular activity of different shooting distances, different release techniques, and different performance levels, with and without stabilizers, in target archery. J Sports Sci 1990;8:235-57.

31. Ertan H, Soylu AR, Korkusuz F. Quantification the relationship between FITA scores and EMG skill indexes in archery. J Electromyogr Kinesiol 2005;15:222-7.

Figures

Shinohara Fig. 1. jpg

Method of measurement



Schematics indicating (a) placement of the cameras, (b) angles of horizontal extension of the shoulder and flexion of the elbow, and (c) the angles of scapular elevation and shoulder abduction.

Shinohara Table 1. doc.

Characteristics of archers who were classified as either impingement or uninjured.

		Impingement	Uninjured	p value	
Number		8	22	–	
Age	(years)	17.1 ± 1.6	17.8 ± 1.7	0.238	
Height	(cm)	172.5 ± 4.0	169.0 ± 3.9	0.067	
Body weight	(kg)	56.9 ± 5.9	62.9 ± 9.7	0.106	
BMI	(%)	19.1 ± 2.0	22.1 ± 3.6	0.055	
Bow weight	(lb)	41.9 ± 1.5	42.6 ± 1.8	0.284	
Years of training	(years)	2.1 ± 1.6	2.8 ± 1.7	0.279	
Joint angles					
Scapular elevation	(degree)	92.9 ± 8.7	85.7 ± 6.0	0.018	*
Shoulder abduction	(degree)	99.2 ± 8.4	103.4 ± 7.7	0.206	
Horizontal extension	(degree)	135.8 ± 16.1	152.2 ± 8.3	0.040	*
Elbow flexion	(degree)	138.9 ± 4.9	143.3 ± 5.1	0.039	*
Muscle activity					
Upper trapezius	(%MVC)	73.1 ± 20.4	59.9 ± 12.3	0.036	*
Lower trapezius	(%MVC)	34.6 ± 9.9	47.0 ± 12.1	0.011	*
UT/LT		2.15 ± 0.47	1.32 ± 0.28	0.001	**
Deltoid posterior	(%MVC)	102.3 ± 13.3	109.1 ± 22.7	0.416	
Deltoid middle	(%MVC)	96.5 ± 50.7	65.3 ± 21.2	0.022	*
Biceps brachii	(%MVC)	39.7 ± 15.5	41.2 ± 22.6	0.856	
Triceps brachii	(%MVC)	19.8 ± 12.6	14.9 ± 7.0	0.180	

*: $p < 0.05$ **: $p < 0.01$

Data are number of patients or mean ± SD.

BMI: body mass index.

UT: upper trapezius; LT: lower trapezius; UT/LT: the ratio of muscle activity of the upper trapezius and lower trapezius.

Shinohara Table 2. doc.

Logistic regression analysis for predicting risk factor of shoulder impingement syndrome in archers

Predictor	Odds ratio	(95% CI)	p value	
UT/LT	1.686[a]	(0.000, 0.375)	0.016	*
Scapula elevation	1.173	(0.662, 1.096)	0.213	
Hosmer-Lemeshow test	$\chi^2 = 11.952$		0.153	

*: $p < 0.05$

The value of "a" shows the odds ratio as 0.1 change.