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Radiological and biomechanical analysis of humeral fractures occurring during arm wrestling

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- A Study Design
- B Data Collection
- C Statistical Analysis
- D Data Interpretation
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Summary

Background: Arm wrestling has recently become one of the most popular sports among young people, mainly due to its simplicity and spectacularity. Yet, unfortunately it is also injury prone. The aim of the study was to perform a biomechanical analysis of the forces which act during arm wrestling, as well as to explain the mechanism of the occurrence of humeral fractures of a similar topology as observed on X-rays.

Material/Methods: During the period 2001 to 2008 nine cases of humeral fractures resulting from arm wrestling were consulted and treated at the Clinic. The assessment of the limb condition included an interview and the examination of the fractured extremity. All the patients underwent surgical treatment, using the method of open reduction and internal fixation. The virtual dynamic model of the upper limb was established on the basis of a series of computer tomography scans of the bone, and literature data. The biomechanical analysis was carried out using the Finite Elements Method (FEM).

Results: There were five cases of the 12-B1 type in the AO Classification with butterfly fragments in five cases, and four of the 12-A1 type without the butterfly fragment. The maximum bone stress resulting from torsional loading which occurs during arm wrestling amounted to 60 MPa and was located 115 mm above the elbow on the medial - posterior side of the humeral.

Conclusions: The strength analysis carried out during arm wrestling revealed that the forces of the acting muscles significantly exert stresses within the distal third of the humeral.

key words: **arm wrestling • humeral fractures • biomechanical analysis**

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Background

Arm wrestling has become a popular sport practiced by both professionals and amateurs. Its popularity comes from the fact that the rules are simple, it is spectacular and does not require the use of complicated equipment [1,2]. However, compared to other sport disciplines, it is considered to be neither benign nor safe as it leads to the occurrence of numerous injuries. In the relevant literature there have been several cases of humeral fractures and soft tissue damage reported [2–9]. In 1, 8–18% of such cases, apart from a fracture, a radial nerve injury has also been observed [1,10–13].

Objective

The aim of this study was to perform a biomechanical analysis of the forces which act during arm wrestling, as well as to explain the mechanism of the occurrence of humeral fractures of a similar topology as observed on X-rays.

Material and methods

Subjects

For the period from 2001 to 2008 nine patients with humeral fractures resulting from arm wrestling were consulted and treated at the Clinic. Among them were 8 men and 1 woman aged from 19 to 41. The follow-up period ranged from 2 to 17 days. Only one person, the woman, was a professional competitor who during the fight had gained advantage over her opponent. The others suffered their injuries while being in defense, during 'home' challenges.

Clinical methods

The assessment of the limb condition included an interview, an examination of the fractured extremity and X-rays. All the patients underwent surgical treatment, using the method of open reduction and internal fixation. One of the fractures was fixed with an AO plate and screws, while five were fixed with LCP plates and screws. One of the spiral fractures (without displacement) was stabilized with a ZESPOL device and the last of the patients was treated with EISIN wires. Three out of nine fractures were accompanied by the radial nerve impairment. The average time of hospital treatment was 6 days (from 2 to 17 days). There were no surgical complications noted.

Radiological analysis

X-rays of the anterior – posterior and lateral projection were made in order to determine the type of fractures and the course of healing. An AO Classification to determine the type of fractures was used. In order to compare and analyze the type and location of fractures, computer programs were used (Adobe Photoshop and Paint Microsoft Office) to create schemes of the fracture line course.

Biomechanical analysis

The adult male right humeral bone was taken for biomechanical analysis. The virtual model of the humeral was established on the basis of the computer tomography scans of the bone obtained from a cadaver. The biomechanical analysis was carried out using the Finite Elements Method (FEM). Aluminum (Young module =0.675 MPa and the Poisson ratio was v=0.33), which is characterized by strength properties similar to the human bone, was used as the analyzed material (Figure 1).

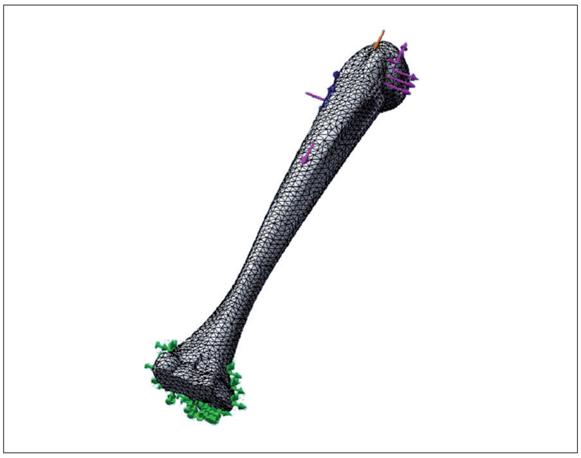

Figure 1. The humeral bone model with the mesh of finite elements including assigned boundary conditions.

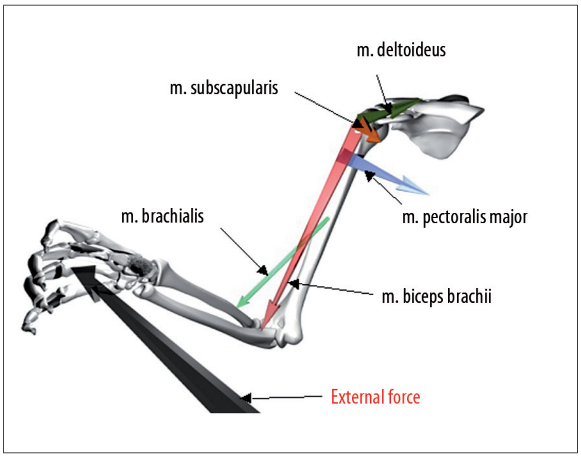

Figure 2. The way strength is applied. External force is equalized by the competitor's muscles.

By using the computer programs Primal Pictures (London UK) Adobe Photoshop and Paint a virtual model of the upper limb of an adult male of average body built was contructed (Figure 2). The external geometrical structure of the bone and the mechanical properties of the muscles, such as internal rotators and forearm flexors, were also taken into consideration. The virtual dynamic model was established on the basis of the literature data [14–16].

It was assumed that during wrestling muscles maintain the elbow hinge joint in flexion. It was also assumed that the bone was immobilized there. Rotational motion occurs only in the shoulder joint. Forces with values and action directions characteristic for muscles: deltoideus, biceps brachii, brachialis – which serve to maintain the arm in flexion, and subscapularis, pectoralis major – which serve to turn the arm inward, were applied to our model. It was assumed that during wrestling these muscles undergo maximum contraction

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Table 1. Muscle parameters [Pennestri and Stefanelli, 2007]: L_0 – muscle length, F_0 – maximal isometric force.

Muscle	L_0 (mm) muscle's length	F_0 (N) maximal isometric force
Deltoid	200	63
Pectoralis major	190	210
Supraspinatus	105	98
Biceps brachii	270	90
Brachialis	105	167

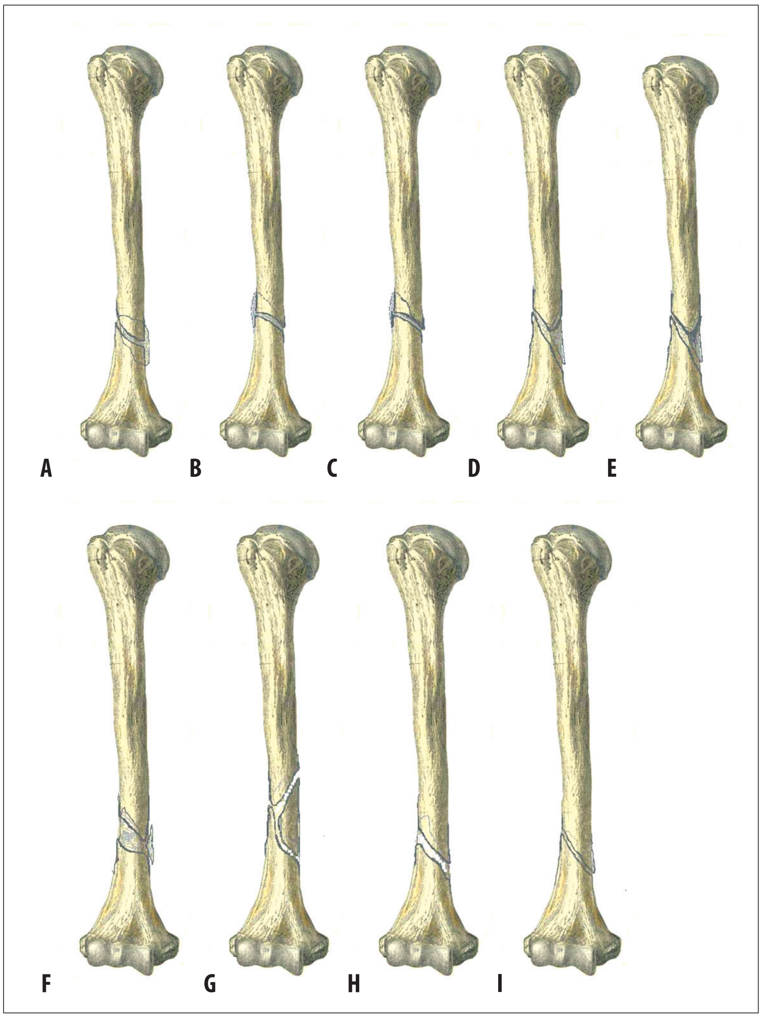

Figure 3. The scheme of the fracture line courses in the analyzed cases.

(Fo). The biomechanical parameters of muscles were quoted from literature data [14], developed for the model of 24 muscles which make up the upper extremity. For each muscle the following parameters have been accepted (Table 1).

Results

Clinical results

In three patients with spiral fracture, the radial nerve was found before surgery and was also observed after the operation. There were no surgical complications.

Radiological results

Radiological assessment showed that in 5 patients a displaced spiral fracture of the distal third of the humeral bone was present. There were five cases of a 12-B1 type in a AO Classification with butterfly fragment (Figure 3A,D,E–G) and four of a 12-A1 type without butterfly fragment (Figure 3B,C,H,I,).

In all cases after surgery the stable fixation of the fracture was achieved.

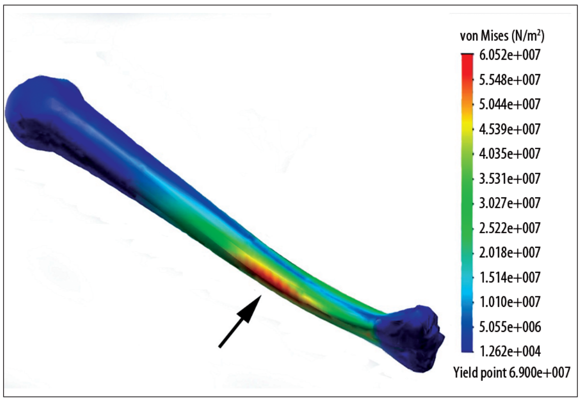

Figure 4. Distribution of stresses obtained from the 3 D model of humeral bone. Red color was used to mark the maximum stress of the humeral bone (arrow) taking into consideration forces of muscles given in Table 1.

Biomechanical results

Maximum bone stress resulting from the torsional loading which occurs during arm wrestling amounts to 60 MPa and is located 115 mm above the elbow on the medial - posterior side of the humeral bone. Stress distribution is typical for torsional loading. As a result of torque actions the fracture line runs at an angle of 45 deg to the longitudinal axis of humeral (in this case to the bone axis). The distribution of stresses has been presented on the 3 D model (Figure 4).

Discussion

Arm wrestling is a very simple and popular sport. Unfortunately, it can be the cause of serious fractures within the upper limb which have been reported in the relevant literature. Ahcan and Ales [2] have discussed one case, Heilbronner, Manoli, Morawa [17] 2 cases, Moon, Kim, Suh, Hwang [18] have discussed seven cases. Only in one article, that of Ogawa and Uil [12], have we found an analysis of the fracture location and line, carried out on the basis of 30 cases which are similar to the cases analyzed in our paper. Nine cases were presented and discussed in our article. All of them were amateurs who broke their arm while arm wrestling.

In Ogawa and Uil's study [12] an analysis of competitors strength advantage is considered. Among the 30 competitors with humeral fractures, their opponents were weaker in 4 cases, in 17 cases the opponents were of a similar strength and in 7 cases the opponents were bigger and stronger. A moment before the fracture occurrence 17 persons were in the phase of indirect fight, 9 were losing, and 4 were winning. In the earlier reports [6,12,13] it was stated that the advantage, as well as the fight phase do not have an influence on the occurrence of the competitor's humeral bone fracture. In our group of patients only one of the competitors had a significant advantage over the opponent and was winning the fight when the fracture took place. This may indicate that force predominance does not decide on the injury. Particular attention should be paid to the arm placement and technique of wrestling.

Fractures of the humeral shaft can be complicated by radial nerve palsy. [2,8–13,18,19] The radial nerve palsy occurs in 1.8–18% of cases, on the average in 11% in Ahcan and Ales [2] while it also occurred in 3 out of the 9 cases in our study.

The humeral fracture mechanism during wrestling has been described by Brismar and Spangen [10] and supplemented by Ogawa and Uil [6,12]. According to the authors the humeral shaft fracture occurs when moments of torsional forces are transmitted onto it. The effect of the indirect injury causes the occurrence of a fracture beyond the place of force application. The moments of these forces are the resultant of forces acting in the direction of external rotation (the opponent's force), and the resultant of forces acting in the direction of internal rotation (the competitor's force). In both cases the resultants of an opposite directions occur thanks to the work of the internal rotator shoulder muscles (m. pectoralis major, m. latissimus dorsi, m. teres major and m. subscapularis). When the dominant competitor is in the attack, the internal rotator muscles of the attacked person undergo rapid stress, from their maximum concentric contraction to eccentric passive compensatory relaxation, causing an increase in the humeral rotational force. This results in the transmission of the stress through the distal part of the arm and elbow resulting in a shifting of the maximum force to the humerus and its fracture. Rotating forces cause rotation around the long axis and a slight push within the transverse plane and the combination of a compression and tension maximum within the plane of 45 degrees from the long axis. In the mechanism described and accepted for analysis we used forces with values and action courses characteristic for the following muscles: m. m. deltoideus, biceps brachii, brachialis, subscapularis, pectoralis major. It was assumed that during wrestling these muscles undergo maximum contraction.

The analysis carried out revealed that forces of acting muscles cause significant loadings in 1/3 of the distal humerus. The resultant stresses are approximate to the boundary values after an exceeding in which there follows a fracture. In the biomechanical analysis only the muscles responsible for the shoulder internal rotation have been taken into consideration which is in accordance with the fracture mechanism proposed by Brismar and Spangen [10]. The distribution of stresses in the bone model is characteristic for torsion which causes the fracture line in 1/3 of the distal humerus at an angle of 45 degrees to the axis, for which there occurs the material mechanical properties change. Approaching the bone strength limit suggests that the muscles which equalize the force of internal rotators play a very important role during wrestling. In the accepted model the influence of the bone internal structure and the course of the marrow cavity was not accounted for. Only the bone external geometry had an impact on the stress distribution. Also, after having applied forces with values quoted from the literature [14] it was found that the permitted values were exceeded 4–5 times. This mechanism refers only to the humerus. The authors did not describe the techniques used by the player during the arm wrestling contest. Taking into consideration and analysing solely the internal rotators does not take into account the sport's technique. It is characteristic for amateurs, who are the most injury prone.

Conclusions

1. The biomechanical conditions occurring within the humerus and the distribution and action course of the

muscles force that occur during arm wrestling account for the repeatability of the fracture location in our model as well as in the radiological findings.
2. To explain the phenomenon, it is necessary to describe the techniques used by a player during an arm wrestling competition. Amateurs are injury prone because they use bad wrestling techniques. They often stabilize the arm in the shoulder (gleno – humeral) joint.

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