Radiological and biomechanical analysis of humeral fractures occurring during arm wrestling

Jacek Kruczyński1, Jarosław Jaszczer Nowicki2, Tomasz Topoliński3, Grzegorz Srokowski4, Grzegorz Mańko5, Marzena Chantsoulis6,7, Małgorzata Frankowska8, Paweł Frankowski8

1 Department of Physiotherapy, University of Bydgoszcz in Bydgoszcz, Bydgoszcz, Poland
2 Academy of Physical Education and Sport in Gdansk, Gdansk, Poland
3 Department of Mechanical Engineering and Mechatronics, University of Technology and Life Sciences (UTR) in Bydgoszcz, Bydgoszcz, Poland
4 Department of Kinesitherapy and Medical Massage, Nicolaus Copernicus University (UMK) in Torun, Collegium Medicum (CM) in Bydgoszcz, Bydgoszcz, Poland
5 Department of Ergonomics and Exertion Physiology, Institute of Physiotherapy, Faculty of Allied Health Sciences, College of Medicine, Jagiellonian University in Cracow, Cracow, Poland
6 Department of Physiotherapy, Academy of Physical Education, Wroclaw, Poland
7 Department of Neurosurgery, Military Hospital No.4, Wroclaw, Poland
8 Department of Orthopedics and Traumatology, Nicolaus Copernicus University (UMK) in Torun, Collegium Medicum (CM) in Bydgoszcz, Bydgoszcz, Poland

12-B1 type, 12-A1 type, AO Classification, butterfly fragments, maximum bone stress, biomechanical analysis, arm wrestling, humeral fractures.

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
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).

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 build was constructed (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...
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).

### 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                              |

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.

### 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.
nerve palsy. [2,8–13,18,19] The radial nerve palsy occurs in Fractures of the humeral shaft can be complicated by radial
ment and technique of wrestling. Particular attention should be paid to the arm place -
decide on the in- wining the fight when the fracture took place. This may in-
tors had a significant advantage over the opponent and was
The resultant forces acting in the direction of external ro-
the mechanism described and accepted for analysis we used forces with val-
ses which are similar to the cases analyzed in our paper. Nine
ecess to the axis, for which there occurs the material me-
the bone model is characteristic for torsion which causes the
m. teres major and m. subscapularis). When the dominant
resultant of forces acting in the direction of external ro-
resultant of forces acting in the direction of internal rotation (the competi-
when the dominant competitor is in the attack, the internal rotator muscles of the
vantages which are typical for arm wrestling. In the accepted model the influence of the bone internal struc-
ity and the course of the marrow cavity was not accounted
In Ogawa and Uil’s study [12] an analysis of competitors
chance (the opponent’s force), and the resultant of forces acting in the direction of internal rotation (the competi-
the resultant stresses are approximate to the boundary values after an exceeding in which there follows a fracture. In the
by Brismar and Spangen [10] and supplement-
ed 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 in-
forces of muscles: m. pectoralis major, m. latissimus dorsi,
m. teres major and m. subscapularis. When the dominant

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 - poste-
ors which are characteristic for amateurs, who are the most injury prone. 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

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 rele-
In Ogawa and Uil’s study [12] an analysis of competitors

The humeral fracture mechanism during wrestling has been described by Brismar and Spangen [10] and supplement-
ed 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 in-

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 me-

Conclusions

1. The biomechanical conditions occurring within the hu-
merus and the distribution and action course of the

Fractures of the humeral shaft can be complicated by radial
erve palsy. [2,8–13,18,19] The radial nerve palsy occurs in
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.

REFERENCES:

1. Chao SL, Molier M, Teg SW: A mechanism of spiral fracture of the humerus. Report of 129 cases following the throwing of hand-grenades. J Trauma, 1971; 11: 602
2. Ahcan U, Ales A: Spiral Fractures of the humerus caused by armwrestling. J Trauma, 2000; 6: 308–11
3. Biondi J, Bear TF: Isolated rupture of the subscapularis tendon in an arm wrestler. Orthopedics, 1988; 11: 647–49
4. Khashaba A: Broken arm wrestler. Br J Sports Med, 2000; 34: 461–62
5. Nyska M, Peiser J, Lukiec F et al: Avulsion fracture of the medial epicondyle caused by arm wrestling. Am J Sports Med, 1992; 20: 347–50
6. Ogawa K, Uil M: Fracture-separation of the medial humeral epicondyle caused by arm wrestling. J Trauma, 1996; 41: 494–97
7. Pasquina PF, O’Connor FG: Olecranon fracture sustained in arm wrestling. Phys Sports Med, 1999; 27: 81–83
8. Whitaker JH: Arm wrestling fractures: a humeral twist. Am J Sports Med, 1977; 5: 67–77
9. Yavouz Y, Yurumez Y, Levent A: Spiral fracture of the humerus during arm wrestling. Med J Kocatepe, 2006; 7: 75–77
10. Brismar B, Spangen L: Fracture of the humerus from arm-wrestling. Acta Ortop Scand, 1975; 46: 707–8
11. De Barros JW, Oliveira DJ: Fractures of the humerus in arm wrestling. Br J Orthop, 1995; 19: 396–91
12. Ogawa K, Uil M: Humeral shaft fracture sustained during arm wrestling: report of 30 cases and review of the literature. J Trauma, 1997; 42: 243–46
13. Owen TD: Humeral fractures in “arm wrestlers”. Br J Clin Pract, 1992; 46: 98–99
14. Pennestrì S, Stefanelli R: Virtual musculo-skeletal model for the biomechanics analysis of the upper limb. J Biomech, 2007: 40: 1350–61
15. Taylor R, Zheng C, Jackson RP et al: The phenomenon of twisted growth: Humeral torsion in dominant arms of high performance tennis players. Comput Meth Biomech Biomed Eng, 2007; 6: 1–14
16. Holzbaur KR, Murray W, Delp SL: A model of the upper extremity for simulating musculoskeletal surgery and analyzing neuromuscular control. An biome工程, 2005; 6: 829–40
17. Heilbronner DM, Manoli A, Morawa LG: Fractures of the humerus in arm wrestlers. Clin Orthop, 1980; 149: 169–71
18. Moon MS, Kim HH, Suh KH: Arm wrestlers’ injury: report of seven cases. Clin Orthop, 1980; 146: 219–21
19. Tomaszewski W, Manko G: An evaluation of the strategic approach to the rehabilitation of TBI patients. Med Sci Monit, 2011; 17(9): CR510–16