Biomechanical analysis of discus athletes’ acute injury of shoulder joint at the beginning phase of rotation.

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Abstract

To further clarify possible sports injury of shoulder joint of excellent discus athletes at beginning phase of rotation and biomechanic characteristics demonstrated, the paper adopts close range dynamic stereo photography measurement method for fixed-point shooting of live competition, training of discus athletes. Comprehensive analysis and research of motion image and information is done with professional video, finally biomechanical indexes of athletes are obtained, and in-depth inquiry is done for possible sports injury of shoulder joint at beginning phase of rotation and biomechanical characteristics demonstrated. Results show that the highest constituent ratio of shoulder joint injury of excellent discus athletes comes from injury of tendon of long head of biceps brachii, followed by rotator cuff injury, acromioclavicular joint sprain and dislocation, dislocation and subluxation (glenohumeral joint), deltoid muscle strain. Biomechanical results show that biomechanical indexes of shoulder joint at beginning phase of rotation are as follows: right from the moment of lifting of right foot, shoulder and hip angle is 45 degrees, pulling angle is 126 degrees, shoulder axis angle is 2 degrees, velocity of left shoulder is 2.64 m/s, velocity of right shoulder is 0.95 m/s; right from the moment of lifting of left foot, shoulder and hip angle is 27 degrees, pulling angle is 150 degrees, shoulder axis angle is -12 degrees, speed of left shoulder is 1.96 m/s, speed of right shoulder is 1.97 m/s. In conclusion, at beginning phase of rotation, increased pulling angle caused the highest ratio of injury of tendon of long head of biceps brachii. Therefore, in the daily training and competition, adjusting of corresponding angle should be a focus.

Keywords: Discus movement, Shoulder joint, Acute injury, Biomechanical analysis.

Introduction

Biomechanics is a biophysics branch of quantitative research of biology mechanics problems with principles and methods of mechanics. Its research scope ranges from biological whole to the system, organs (including blood, body fluids, organs, bones, etc.), from bird flying, fish swimming, flagellum and ciliary movement to transportation of plant body fluid, etc. The basis of biomechanics is the law of energy conservation, law of momentum, three laws of mass conservation and constitutive equation describing physical properties [1-3]. Biomechanics mainly applies physical laws and engineering concepts to describe the relationship between dynamic and force. Weiss et al. showed that biomechanics was associated with patellofemoral pain and anterior cruciate ligament (ACL) injuries in sports [4]. Discus sport is a main type of throwing with very common sports injury problems, mainly muscle ligament sprain or fracture due to insufficient preparation activities at training and competition or unskilled techniques [5]. A study showed an analysis of biomechanics on the sports injury of the knee joint at stage of high rising transition in male discus athletes [6]. Another research on the technology training of discus throw based on the sports biomechanics have been also reported [7]. In addition, as technical characteristics can also cause fatigue damage, throwing events often need extraordinary range of abnormal joint activities. Kinematics can provide quantitative description of joint activities range, provide scientific basis for avoiding damage and changing sports rule, and provide basis for improvement of protective equipment. The shoulder is the body’s most mobile joint, and injury of discus athletes largely occurs in the shoulder joint [8,9] (Figure 1). However, the biomechanical analysis of discus athletes’ acute injury of shoulder joint was limited. Therefore, in this study, we aimed to further clarify possible sports injury of shoulder joint of excellent discus athletes at beginning phase of rotation. In order to provide more reasonable training methods to excellent discus athletes and improve performance, this paper conducts in-depth analysis of shoulder joint injury problems of discus athletes from point of view of biomechanics with specific circumstances.
Method

General information

Subjects: 400 excellent discus athletes during March 2012 - March 2015, with 230 male athletes, 174 female athletes were enrolled in this study. Follow-up survey with 404 questionnaires was issued every year and 1212 questionnaires were issued in three years.

Figure 1. Shoulder muscles and bone constitution.

Questionnaire survey

The main contents of the questionnaire include cause of shoulder joint, nature of injury and injury site, to understand constituent ratio of shoulder joint injury of discus athletes.

Measurement method

In June 2014, close range dynamic stereo photography (Company in China) measurement method is taken for fixed-point shooting of athletes’ live match and training, with shooting frequency regulated at 50 Hz [10]. Motion video rapid feedback analysis system is adopted to fulfill image sampling and data calculation.

Biomechanical indexes

Indexes of shoulder and hip angle, pulling angle, shoulder axis angle, velocity of left shoulder, velocity of right shoulder from the moment of left foot touchdown to disposing of discus.

Table 1. Shoulder joint angle and speed change from the moment of lifting of right foot to the moment of lifting of left foot.

<table>
<thead>
<tr>
<th>Timing</th>
<th>Shoulder hip (degrees)</th>
<th>Pulling (degrees)</th>
<th>Shoulder (degrees)</th>
<th>Pulling (degrees)</th>
<th>Shoulder axis angle</th>
<th>Velocity of left shoulder (m/s)</th>
<th>Velocity of right shoulder (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The moment of lifting of right foot</td>
<td>44 ± 1</td>
<td>127 ± 6</td>
<td>2 ± 1</td>
<td>2.64 ± 1.21</td>
<td>0.99 ± 0.41</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The moment of lifting of left foot</td>
<td>26 ± 5</td>
<td>150 ± 3</td>
<td>-11 ± 3</td>
<td>1.97 ± 0.33</td>
<td>1.92 ± 0.73</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Musculus biceps brachii is one of the most important upper limb muscles. Tendon of biceps brachii connects musculus biceps brachii and bone. Its role includes: elbow flexion, supination of forearm, lower head of humerus, shoulder flexion. Musculus biceps brachii is divided into two tendon of caput longum and brachycephaly at shoulder joint. Caput

Observation index

Constituent ratio of discus athletes’ shoulder joint injury at stage of final exertion, indexes of shoulder and hip angle, pulling angle, shoulder axis angle, velocity of left shoulder, velocity of right shoulder from the moment of left foot touchdown to disposing of discus. The inclusion criteria: all participants were discus athletes.

Statistical methods

SPSS19.0 statistics software is used to complete data entry and output, with average number ± mean value to denote measurement data and t value for test.

Ethical consideration

The study was carried out in compliance with the Declaration of Helsinki of the World Medical Association, and according to a protocol approved by Shaanxi University of Chinese Medicine, the approval number is 2012009. The objectives of the study were explained to the study participants and verbal consent was obtained before interviewing each participant.

Results

The 1212 questionnaires are issued to participants based on quantitative analysis, with all recovered, with efficiency at 100%. Data result of 1212 questionnaires are simultaneously analyzed by investigation team. Subjects were on average of (21.43 ± 2.95) years old. Based on shoulder joint injury nature and injury site of 400 excellent discus athletes, the highest constituent ratio of shoulder joint injury comes from tendon of long head of biceps brachii, 34.65% (420/1212); followed by rotator cuff injury, 23.76% (288/1212); acromioclavicular joint sprain and dislocation, dislocation and subluxation (glenohumeral joint), deltoid muscle strain and other injuries constitute 11.88% (144/1212), 1.98% (24/1212), 7.92% (96/1212), 19.81% (240/1212).

Refer to the following table for relation between shoulder joint angle and speed change from the moment of lifting of right foot to the moment of lifting of left foot of 400 excellent discus athletes. The shoulder joint angle and speed change from the moment of lifting of right foot to the moment of lifting of left foot is shown as Table 1.
longum goes over the superior humeral head and is attached to
glenoid, the part most likely to cause symptoms. Musculus
biceps brachii and musculus triceps brachii together constitute
main part of upper arm, muscle group located in the front of
the upper arm. In terms of its function, mainly flexion of the
arm exerts to complete all pulling action and assist in activities
of muscle group at the back towards the outside world.

Rotator cuff is a group of tendon complex wrapped around
humeral head. The front of humeral head is subscapularis
tendon, upward side is supraspinatus tendon, the rear part is
infraspinatus tendon and teres minor tendon. Movement of
these tendons results in shoulder internal rotation, external
rotation and lifting activities, but the more important is that
these tendons stabilize humeral head in the glenoid, which
plays an extremely important role in maintaining shoulder joint
stability and activity of shoulder joint.

Shoulder girdle is composed of 5 joints, namely glenohumeral
joint, acromioclavicular joint, sternoclavicular joint, joint
between the chest wall and the shoulder and acromion humeral
joint. Therefore, any joint injury will affect shoulder movement
function in varying degrees. The shoulder joint is with
maximum human body activity. Because of small size of
glenoid, and as humeral head is big and round, joint capsule is
relatively loose, glenohumeral joint is with high activity, which
is different from hip. Plus rise and fall, rotation of scapula and
its orbiting (adduction and abduction) along the chest wall,
scope of activities is greater. Therefore, during movement, the
shoulder can complete a wide range of relatively complex
actions and thus is prone to hurt. Instant action from lifting of
right foot to lifting of left foot is to begin rotation for the sake
of body stability, increase moment of inertia, reserve energy
and create favorable conditions for rotational speed at flight.

Discussion

Our results showed that at the moment of lifting of right foot,
mean shoulder and hip angle of excellent discus athletes is 45
degrees, mean pulling angle is 125 degrees. At this time,
athletes’ body postures gradually expand through hip twisting
from maximum tightening state at preliminary swing, with
body tightening weakened. At the moment of lifting of right
foot, mean shoulder and hip angle is 26 degrees, mean pulling
angle is 150 degrees. During the moment from lifting of right
foot to lifting of left foot, shoulder and hip angle becomes
smaller, pulling angle becomes larger, the body gradually
expands with right shoulder turning with the left side, and
pulling angle is increased by an average of 23 degrees at this
stage.

Pulling angle increase of excellent discus athletes is relatively
large at this stage. Athletes’ left shoulder extends in the
throwing direction, with right arm passively rolling forward at
the back. The right shoulder excessively extends, rotates and
stretches, velocity of right shoulder increases while velocity of
left shoulder declines. The front structure of right shoulder is in
passive tension and tension. Acromioclavicular joint is formed
of inside end of acromion, outer end of clavicle linked with
joint capsule, acromioclavicular, ligament, deltoïd, trapezius
muscle tendon attachment and coracoclavicular ligament
[11,12]. Acromioclavicular joint function is demonstrated in
lifting and fall of scapula, and scapular adduction and
abduction. With increase in amplitude of variation of pulling
angle, throwing arm fails to turn in throwing direction with
body, but exerts backward, which may be an important factor
in occurrence of acromioclavicular joint sprain and dislocation.
To try to avoid acromioclavicular joint sprain, shoulder girdle
should be appropriately relaxed, throwing arm should turn in
throwing direction with body, without active exertion
backward, which is also a technical requirement to improve
athletic performance. The results show that the highest
constituent ratio of sports injury of national master athletes
comes from injury of tendon of long head of biceps brachii,
35%. Caput longum of musculus biceps brachii begins from
glenoid nodule joint, while tendon descends in joint, passes
through intertubercular groove and connects to vaginae
synoviales with joint capsule. It is the only tendon through
joint in the body. Intertubercular sulcus is narrow, with
transverse ligament protection to prevent tendon dislocation.
The brachyccephalys begins from coracoid, while two muscle
belly gradually integrate into one, separate into two in the
downside, respectively ending at tuber radii and medial
forearm fascia. In addition to elbow flexion and rear
suspension of forearm, musculus biceps can stabilize shoulder
joint and extend humeral at elbow suspension [13]. By
questionnaire survey and three-dimensional biomechanical
analysis of sports, Li found that the sports injury and
biomechanical characteristics of shoulder joint that may appear
in the state outstanding women discus athletes at the beginning
phase of rotation, which was consistent with this study [14]. In
addition, another study also reported an analysis of
biomechanical on the acute injury of shoulder joint of finally
forcibly phase in male discus athletes [15]. Due to relatively
large amplitude increase of pulling angle at this stage, the
highest constituent ratio of injury comes from tendon of long
head of biceps brachii, and increased amplitude of pulling
angle may be an important factor that causes injury of tendon
of long head of biceps brachii. Athletes are thus required to pay
attention to relaxation of the right shoulder girdle after
completion of action. Although the bigger pulling angle is, the
better, the limit should not be overrun to avoid injury of tendon
of long head of biceps brachii. Questionnaire survey results
show that mean shoulder axis angle of national master athletes
at the instant moment of lifting of left foot is -12°; at this
moment, included angle of shoulder and hip axis and
perpendicular plane in throwing direction is located at left front
of throwing circle, while hip axis precedes shoulder axis and
turns to right front of throwing circle.

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