Kinematical Analysis of the Elbow Joint during Push-up

Hamzah Sakeran, Mohd Shahril bin Salim
School of Mechatronic Engineering, Universiti Malaysia Perlis (UniMAP).

Abstract—Muscle strength of upper extremities can be developed with regular pushup exercise training. However, performing pushup in wrong forearm rotation might lead to injuries as a result from excessive shear force acting on elbow joint. The objective of this investigation was to identify the elbow joint, right elbow angle and to develop a biomechanical model based on various data collected about movement involving this joint. The angle of the right elbow joint was investigated under various forearm rotations: neutral position, internal position and external position during pushup. The loading biomechanics of the elbow joint differed with various forearm rotations. The elbow joint angles were significantly affected by forearm rotations.

Keyword—right arm, kinematic, push-up

I. INTRODUCTION

The elbow joint is not a multiaxial joint like hip joint and may be thought of as a simple hinge joint. However the elbow actually encompasses three articulations: the humeroulnar, humeroradial, and proximal radioulnar joints. The functions are to perform lifting and carrying tasks, cushion the body during collisions and lessen body momentum during falls. [1]

The three associated joints at the elbow allow motion in two planes. Flexion and extension are sagittal plane movements that occur at the humeroulnar and humeroradial joints, and pronation and supination are longitudinal rotational movements that take place at the proximal radioulnar joint. [2]

Although the elbow is not considered to be a weight-bearing joint, it sustains significant loads during daily activities. In addition, in many sports, performance also is contingent on the ability of the arms to effectively swing a racquet or club, or to position the hands for throwing and catching a ball.

However, the elbow is often subjected to compressive forces when the arm is placed in a position to cushion a fall or lessen body impact with another object. Microtraumatic forces caused by repetitive valgus and varus stresses also can lead to overuse injuries, many of which are related to poor skill technique. [4]

We are investigating the affects of angle by different of hand position during pushup to elbow joint. This paper only report of the right arm elbow (dominant arm).

II. METHODS

A. Subjects and experimental protocol

The criterion of the subject is that the subject has no history of previous upper-extremity injuries or disorders and was functionally right-handed dominant.

The Vicon motion system with six cameras was used to measure relative joint positions. A set of twenty reflective markers was placed on selected anatomic landmark on the subject. The selected were intended to simulate the rigid body assumption for trunk (vertical vertebra 7, and thoracic vertebra 4), upper arm (acromion process, epicondyles of the elbow), forearm (medial and lateral epicondyles of the elbow, ulnar styloid processes), and hand (radial and ulnar styloid processes, third metacarpal bone), as shown in Fig.1. In addition, a triangular frame with three markers was placed on the upper arm in order to minimize the potential errors due to skin movement.
Subject was asked to completely perform pushup in three rotational positions of hand—neutral, internally rotated (IR) 90°, and externally rotated (ER) 90° (see Fig. 2). Before the start of pushup, subject was asked to keep his body in the neutral anatomic position with arms at his sides and palms facing forward as neutral reference position. He was instructed to perform the first set of five consecutive pushup in neutral position within approximately 10 s. Five minutes was allowed for rest between sets, in order to avoid muscle fatigue. The second and the third sets were done randomly afterwards in either IR or ER hand positions.

B. Joint Coordinate System (JCS)

JCS and motion for the elbow joint (forearm relative to the humerus, Z–X–Y order) [3]

X-axis: The axis fixed to the proximal segment and coincident with the Zh-axis of the humerus coordinate system.

Rotation: flexion (positive) and extension (negative).

Y-axis: The axis fixed to the distal segment and coincident with the Yf-axis of the forearm coordinate system.

Rotation: axial rotation of the forearm, pronation (negative) and supination (supination).

Z-axis: The floating axis, the common axis perpendicular to X-axis and Y-axis, the rotated Xf-axis of the forearm coordinate system.

Rotation: varus (positive) and valgus (negative).
C. Data Reduction

Laboratory-developed kinematics and kinetics software were used to calculate the joint angles of the upper extremity.

Results for neutral position (see Fig. 5 and Fig. 6) was found to have more flexion with maximum 127° during up and minimum 12° during down (SD=39.5). For sagittal plane (Y-axis) the maximum supination is 6.6° and pronation 3.1° (SD=2.50). Besides, for the frontal plane (Z-axis) is more varus with maximum of 18° during up and minimum 6° during down (SD=2.28).

<table>
<thead>
<tr>
<th>TABLE I</th>
<th>JOINT ANGLE OF THE ELBOW AT N POSITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angle</td>
<td>x</td>
</tr>
<tr>
<td>Maximum</td>
<td>127.33</td>
</tr>
<tr>
<td>Minimum</td>
<td>12.61</td>
</tr>
<tr>
<td>Std</td>
<td>39.46</td>
</tr>
</tbody>
</table>

B. Internal position (IR)

Results for IR (see Fig 7 and Fig 8) was found to have more flexion with maximum 120.13° during up and minimum 7.9° during down (SD=40.7). For sagittal plane (Y-axis) the maximum supination is 4.7° and pronation 3.4°(SD=1.93). Besides, for the frontal plane (Z-axis) is more varus with maximum of 23.67° during up and minimum 4.19° during down (SD=5.34).

<table>
<thead>
<tr>
<th>TABLE II</th>
<th>JOINT ANGLE OF THE ELBOW AT IR POSITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angle</td>
<td>x</td>
</tr>
<tr>
<td>Maximum</td>
<td>120.13</td>
</tr>
<tr>
<td>Minimum</td>
<td>7.89</td>
</tr>
<tr>
<td>Std</td>
<td>40.69</td>
</tr>
</tbody>
</table>

C. External position (ER)

Results for ER (see Fig. 9 and Fig. 10) was found to have more flexion with maximum 136.11° during up and minimum 18.7° during down (SD=39.4). For sagittal plane (Y-axis) the maximum supination is 11.6° and pronation 1.02°(SD=3.09). Besides, for the frontal plane (Z-axis) is more valgus with maximum of 6.67° during up and minimum 19.1° during down (SD=3.33).

<table>
<thead>
<tr>
<th>TABLE III</th>
<th>JOINT ANGLE OF THE ELBOW AT ER POSITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angle</td>
<td>x</td>
</tr>
<tr>
<td>Maximum</td>
<td>136.11</td>
</tr>
<tr>
<td>Minimum</td>
<td>18.65</td>
</tr>
<tr>
<td>Std</td>
<td>39.42</td>
</tr>
</tbody>
</table>
IV. DISCUSSION

The joint angles of the IR position were in more varus position in the frontal plane in relatively more flexed position in the sagittal plane and in relatively more pronation position in the transverse plane. The valgus/varus and flexion/extension elbow angles of the down and peak events did not differ from each other in all positions, but the supination/pronation elbow angles were significantly different. The elbow of the IR position was more pronated while that of the ER position was more supinated.

CONCLUSION

The elbow joint angles were significantly affected by forearm rotations. The valgus/varus and flexion/extension elbow angles of the down and peak events did not differ from each other in all positions, but the supination/pronation elbow angles were significantly different.

REFERENCES

**APPENDICES**

**Fig5:** Neutral position for right elbow angle

**Fig6:** Neutral position for right elbow angle for one cycle
Fig 7: Internal position for right elbow angle

Fig 8: Internal position for right elbow angle for one cycle
Fig 9: External position for right elbow angle

Fig 10: External position for right elbow angle for one cycle