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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 identity 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: neutaral position, internal position and external position during pushup. Subject was asked to perform pushup in various forearm rotations: neutral, 90° internal rotation, and 90° external rotation. The loading biomechanics of the elbow joint differed with various forearm rotations. It was noted that greater posterior and varus forces of the elbow are encountered with internal rotation of the hand position and, consequently, full forearm pronation. 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 thoraric vertebra 4), upper arm (accromion 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.

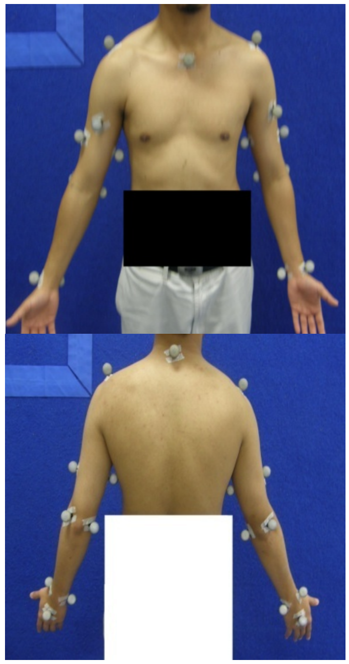
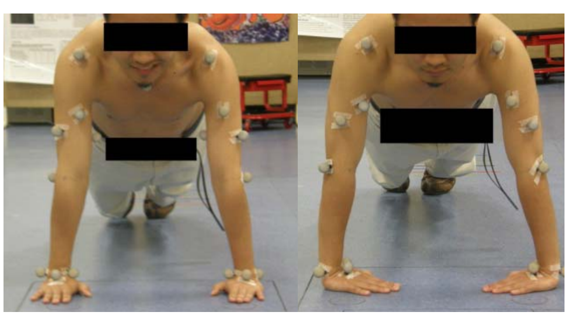


Fig 1. Markers set up in this experiment

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 were 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



(a) (b)

(c)

Fig 2. Three forearm rotations during pushup. (a) Neutral position of the hand. (b) The hand internally rotated 90°. (c)The hand is externally rotated 90°.

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 Y_f-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)

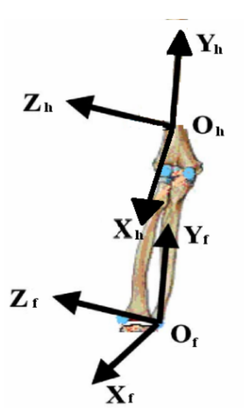
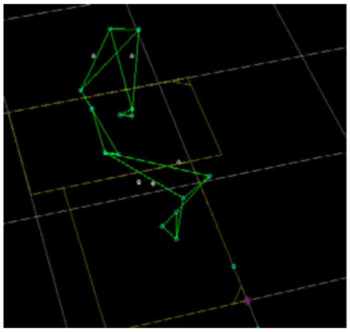


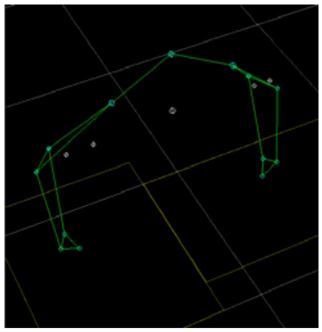
Fig 3. Definition of elbow coordinate system.

C. Data Reduction

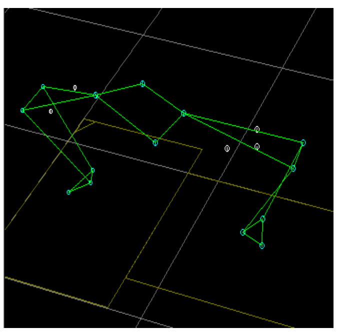
Laboratory-developed kinematics and kinetics software were used to calculate the joint angles of the upper extremity.



(a)



(b)



(c)

Fig. 4. Three forearm rotations during pushup with Body Builder software. (a) Neutral position of the hand. (b) The hand internally rotated 90^o. (c)The hand is externally rotated 90^o.

A three-segment model, i.e. hand forearm and upper arm, was employed in the analysis. Each segment was assumed to be a rigid body. Eight cameras were used to record the 3-D position of the markers. Three joint angles, hinge angle, rotational angle and horizontal deviation, were calculated with a Z-X-Y rotational sequence based on the attached markers

D. Data Analysis

The kinematic data of the elbow between neutral, IR and ER hand positions was analyzed with Microsoft Excel 2007.

III. RESULT

A. Neutral position (N)

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

TABLE I
JOINT ANGLE OF THE ELBOW AT N POSITION

Angle	**x**	**y**	**z**
Maximum	127.33	6.67	18.35
Minimum	12.61	-3.10	6.31
Sd	39.46	2.49	2.28

B. Internal position (IR)

Results for IR (see fig7 and fig8) was found to have more flexion with maximum 120.13^o during up and minimum 7.9^{o}during down (SD=40.7) .For sagittal plane (Y-axis) the maximum supination is 4.7^o and pronation 3.4^o(SD=1.93).Besides, for the frontal plane (Z-axis) is more varus with maximum of 23.67^o during up and minimum 4.19^o during down(SD=5.34).

TABLE II
JOINT ANGLE OF THE ELBOW AT IR POSITION

Angle	**x**	**y**	**z**
Maximum	120.13	4.70	23.67
Minimum	7.89	-3.40	4.19
Std	40.69	1.92	5.34

C. External position (ER)

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

TABLE III
JOINT ANGLE OF THE ELBOW AT ER POSITION

Angle	**x**	**y**	**z**
Maximum	136.11	11.66	-6.67
Minimum	18.65	-1.02	-19.05
Std	39.42	3.08	3.33

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.

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APPENDICES

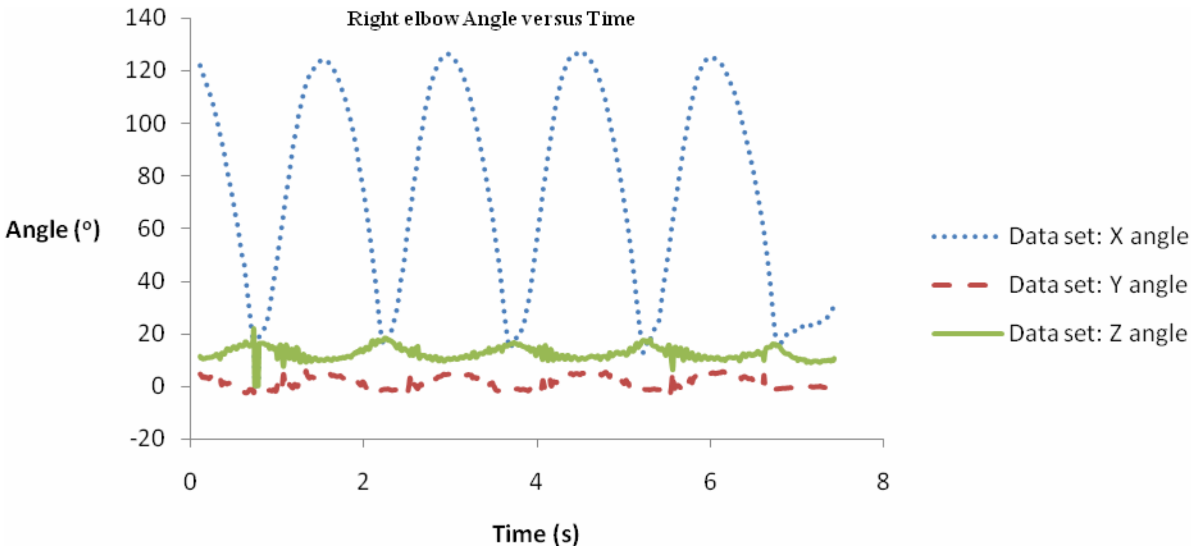

Fig5: Neutral position for right elbow angle

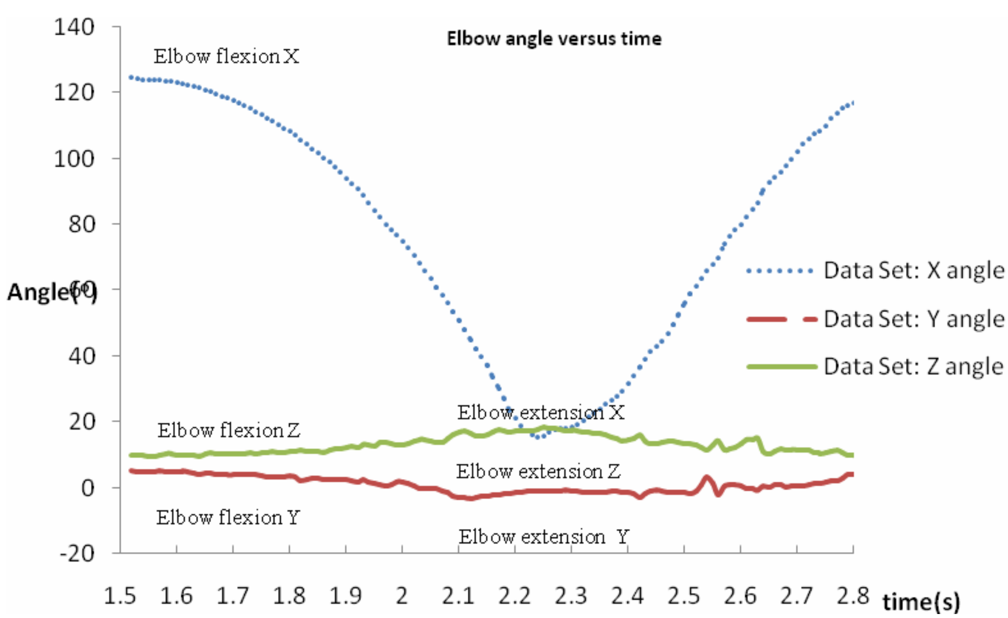

Fig6: Neutral position for right elbow angle for one cycle

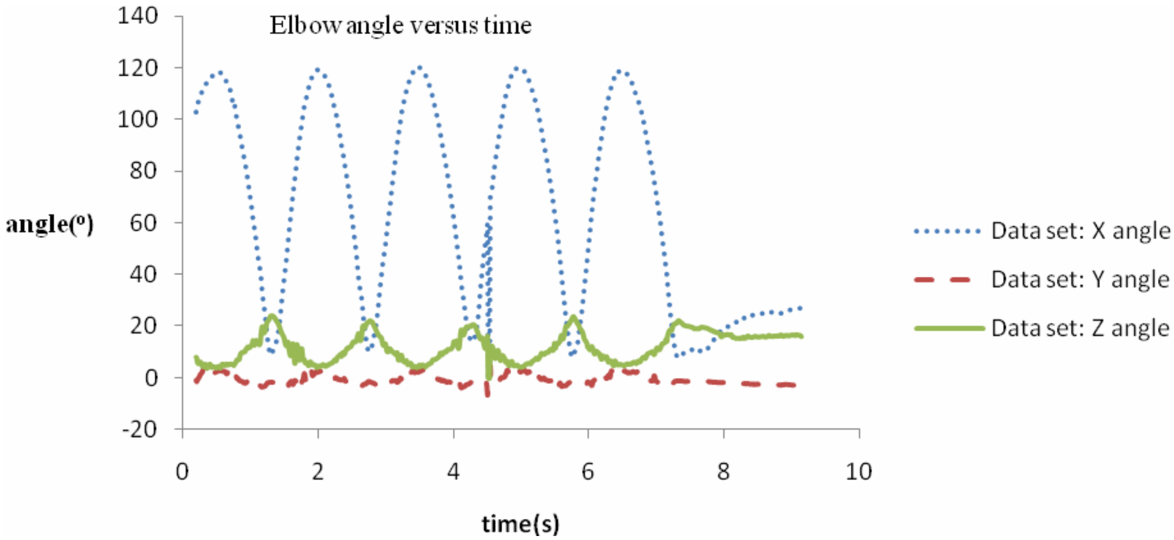

Fig 7: Internal position for right elbow angle

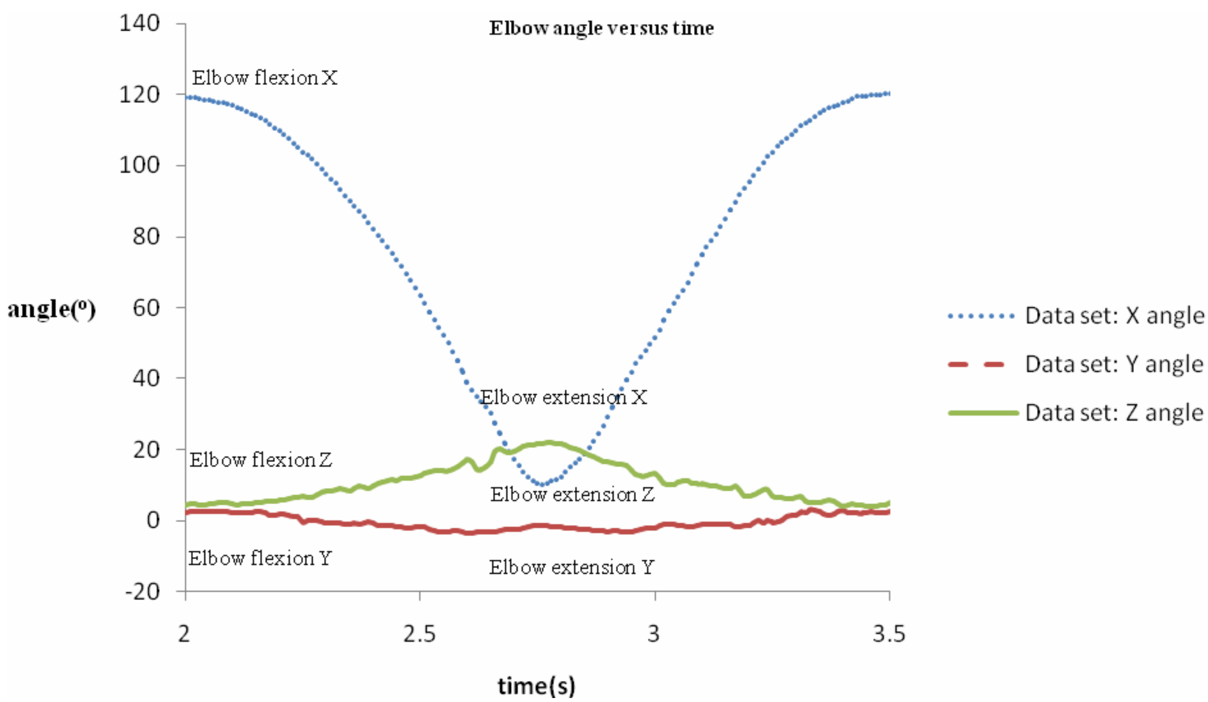

Fig8: Internal position for right elbow angle for one cycle

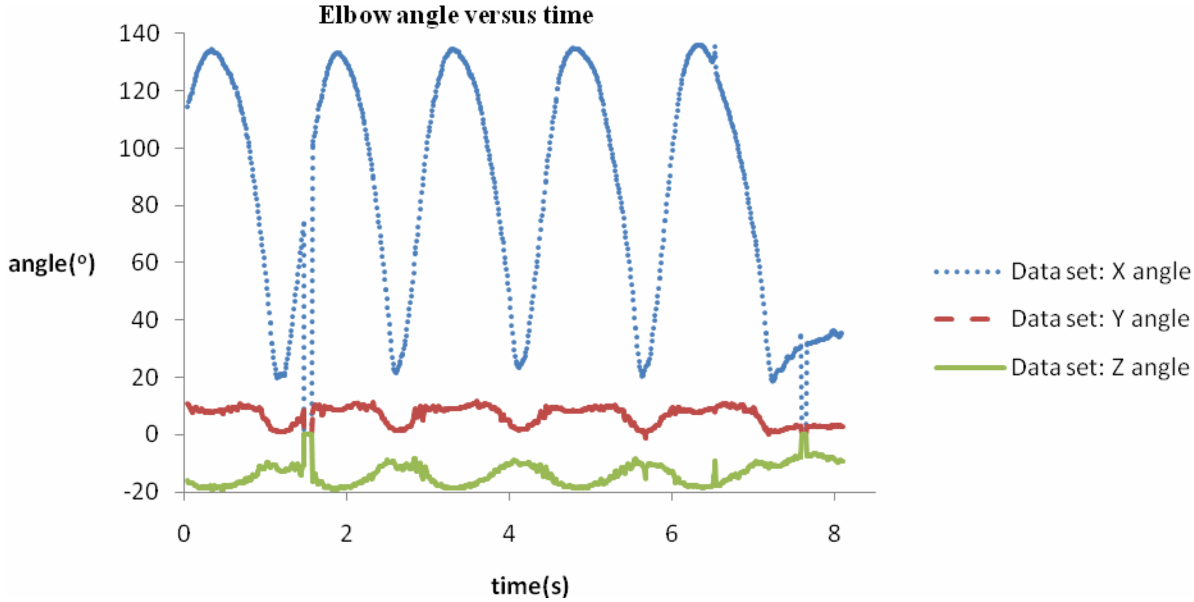

Fig9: External position for right elbow angle

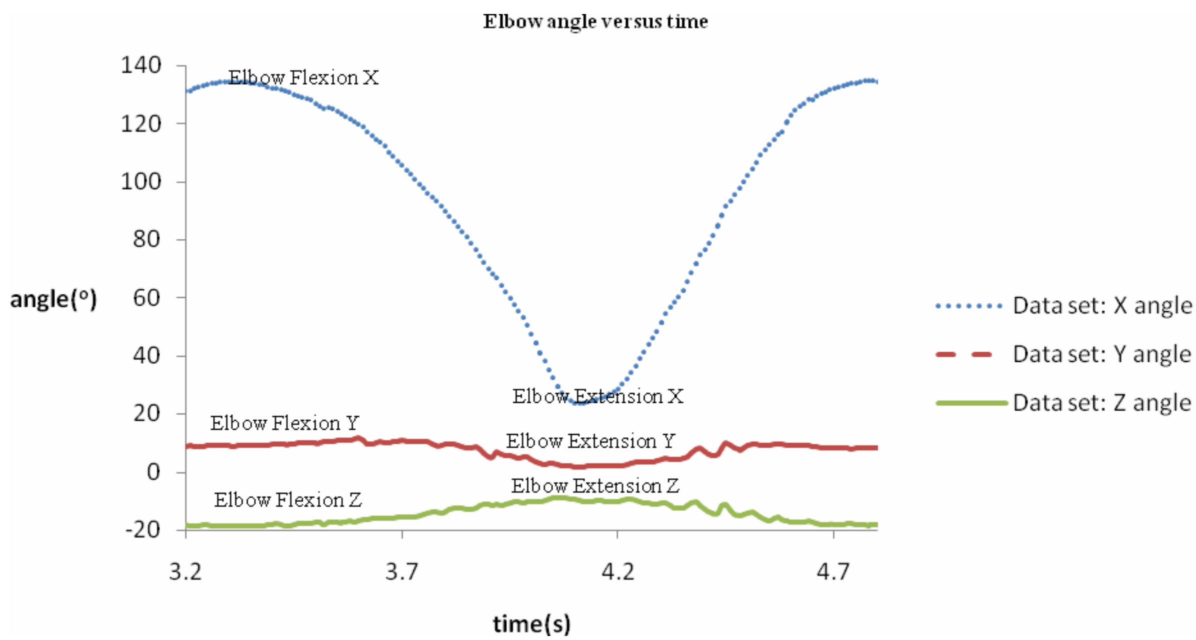

Fig 10: External position for right elbow angle for one cycle