RELATIONSHIP BETWEEN ELBOW FLEXION ANGLE AND JOINT LOADING OF THE UPPER EXTREMITY DURING A CLOSE-CHAIN EXERCISE

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INTRODUCTION

Push-up is a close-chain exercise that is commonly used to strengthen the upper extremity. Clinically, close-chain exercises are encouraged for the earlier stage of the rehabilitation program because they produce smaller shearing forces across the joints than open-chain exercises. Nonetheless, there is very little research regarding the kinematics of the close-chain exercise of the upper extremity. The purpose of this study is to investigate the relationship between the elbow flexion angle and joint loading during a close-chain exercise of the upper extremity.

METHODS

Fourteen male subjects volunteered in this study. Their average age was 24.5 years, with an average height of 168.9 cm, and average weight of 65.9 Kg. The subjects were asked to perform push-up exercises with their hands in neutral position. The Expert Vison motion system (Motion Analysis Corp., Santa Rosa, CA, USA) with six CCD cameras and two Kistler force-plates (Type 9281B, Kistler Instrument Corp., Winterhur, Switzerland) were used to measure relative joint positions and ground reaction forces. The kinematics and kinetics of the upper extremity were calculated by inverse dynamics and Newton-Eulerian's equation. The correlation between the elbow flexion angle and joint loading during a close-chain exercise of the upper extremity were analyzed.

RESULTS AND DISCUSSION

Results showed that the loading biomechanics of the upper extremity differed with different elbow flexion angles. The maximum loading occurred when the elbow flexion angle was greater than 90° ($p<0.01$). The joint forces in axial, medial/lateral, and anterior/posterior directions increased as the degrees of elbow flexion increased (Figure 1). The maximum valgus moment, flexion moment, and pronation moment were 11.2, 39.9, and 9.8 N-m respectively (Table 1). During the push-up exercise, the greatest loading was calculated with the maximum elbow flexion (the lowest trunk position).

In addition to the effective dampers and springs of wrist and shoulder, the elbow played a very important role of energy dissipation. Taking the effect of elbow motion into consideration, our three-mass-model was more precise in simulating the motion of upper extremity during a close-chain exercise [1].

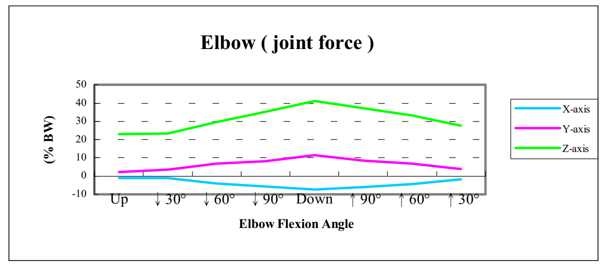

Figure 1: Joint force (% B.W.) vs. degree of elbow flexion angle during a push-up cycle.

Table-1 Joint loading vs. elbow flexion angle

Force	Elbow Flexion Angle					
(% B.W.)	0°	30°	60°	90°	Down	$F^{\#}$ (α)
Med(+) / Lat(-)	-1.3 (1.1)	-1.0 (0.8)	-4.1 (1.7)	-5.9 (2.1)	-7.4 (2.5)	*
Ant(+) / Post(-)	2.2 (1.1)	3.6 (1.9)	6.9 (2.7)	8.2 (3.1)	11.5 (2.9)	*
Axial(+)	23.1 (7.5)	23.4 (9.1)	29.6 (8.7)	35.1 (9.4)	41.0 (11.8)	**
Moment	**Elbow Flexion Angle**					
(N-m.)	0°	30°	60°	90°	Down	$F^{\#}$ (α)
Varus(+) / Valgus(-)	-2.1 (1.5)	3.8 (2.3)	-7.2 (4.1)	-9.9 (3.8)	-11.2 (3.7)	*
Flexion(+) / Extension(-)	12 (3.5)	18.5 (9.6)	22.4 (10.6)	32.6 (12.1)	39.9 (11.5)	**
Supination(+) / Pronation(-)	1.6 (1.1)	3.1 (2.9)	4.6 (3.4)	8.2 (6.3)	9.8 (4.1)	*

$F^{\#}$ value is significance of one-way ANOVA; * ($p<0.05$), ** ($p<0.01$)

CONCLUSION

In this study, the relationship between elbow flexion angle and joint loading during a close-chain exercise were demonstrated. Although the maximum valgus moment during push-up exercise (11.2$\pm$3.7 N-m) was far less than the maximum valgus moment during sports (i.e., 64 N-m in pitching), the peak joint loading occurred between 90 to 120 degrees of elbow flexion. Therefore, keeping elbow flexion less than 90 degrees during a close-chain exercise might be a safer strategy for strengthening of the upper extremity.

REFERENCES

1. Chou, P.H., Lin, C.J., Chou, Y.L., et al. (2002). *Int J Sport Med*, **23(6)**, 457-462

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